THE DISCOVERY OF THE OCEANS

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N. BALAKRISHNAN NAIR

National Council of Educational Research and Training

September 1969
Bhadra 1891

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Rs. 1.45

Published at the Publication Unit, 9 Eastern Avenue, Maharani Bagh, New Delhi 14, by P N Natu, Secretary, National Council of Educational Research and Training, and printed by M. C Khunnah at Job Press Private Ltd., Kanpur.

FOREWORD

THE OCEANS of the world constitute one of mankind's greatest resources. Their potentials are of very great importance to us. Seventy-one per cent of the surface of the earth is covered by oceans. We know many things about oceans but what we do not know is much more. The waters of the sea have many mysteries hidden.

Many phases of human life are influenced by the sea. It is an abundant source of food and minerals. It influences the climate in which we live. It acts as a major highway for transport and also serves as a disposal area for large varieties of waste material. In recent years, several nations have evinced keen interest in the study of oceans. The International Indian Ocean Expedition is one such attempt. India took a special interest in this expedition because of her geographical location. The results of the expedition will provide basic information relating to Indian Ocean and indicate the material resources which could be exploited. Man's conquest of the sea through progressive development of water transport is a story by itself, but equally fascinating is the way in which the secrets of the oceans have been discovered through tireless efforts of marine scientists during the last one hundred years. The renewed awakening in the studies of the 'inner space', more conventionally called oceanography, is now taking place all over the world. A few have even claimed that the ocean beds are going to yield us more mineral resources than the moon 'rocks'. It has become very essential that some information about the oceans in general and the important results of the recent studies be placed before the students of our schools.

When the manuscript of 'The Discovery of the Oceans' was received by us, we felt, after scrutiny, that its contents could be utilised to serve as a book in the series of *Supplementary Readers in Science*. This is the fourth title in the series which aims to stimulate the interest of school children in the science of the oceans and to keep them in touch with the significant developments that are taking place in this field. Prof. Balakrishnan Nair, the author, gives in this book an interesting account of the oceans and their potentialities The book covers a wide variety of topics and is well illustrated. It is hoped that this Reader will help the school students and others to get acquainted with the marine environment. If the persons of the younger generation are made aware of the needs and satisfaction inherent in the pursuit of the ocean studies, we would be soon having a band of scientists working for the betterment of our country.

New Delhi
August 18, 1969

M C PANT
Head, Department of Science Education

PREFACE

Have you ever looked around to see, to appreciate and to enjoy the beautiful sights on our planet? Behold the colourful, fragrant spring, the rainy summer and the cold winter, the blue skies, the fleecy clouds, the lovely rainbow, the flaming sunrises and the glorious sunsets. Watch the mad procession of the dark monsoon clouds, the vivid flashes of lightning, wild claps of thunder, twisting sheets of rain, the rushing rivers and their blissful entry into the wide, wide ocean. These are the beautiful sights of our planet. The brown earth, the green grass, the beautiful bushes, and the tall trees are seen only here. The countless numbers of plants and animals that live on Earth are found nowhere else.

Seventy-one per cent of the surface of our planet is covered by the restless waters of the oceans, the land jutting out like little islands. As we stand on the sea shore to look at this immense, connected body of water it appears strange and endless. The waves in regular rhythm roll in and dash against the shore and break up into silvery foam and salty spray. The tides press forward, recede and return in regular cycles.

This watery world is both mysterious and wonderful. We know very little about this great frontier of Earth. The science that deals with the oceans, oceanography, is a comparatively new branch of science.

Do you know that it was in the tepid, dimly-lit waters of the early seas that the first spark of life appeared on our planet? It was in this salty cradle that the endless varieties of plants and animals appeared and evolved into curious, complex and sometimes crazy types and patterns. From this cradle some living things boldly crept out on to the dry land to become our great ancestors.

The ocean is a veritable store house of valuable chemicals, precious metals and life-saving wonder drugs. The sea can also be a rich source of an unlimited amount of nourishing food for the hungry millions. The present world population is expected to double itself by 2,000 A.D and to provide sufficient food for this exploding population, man will certainly have to look towards the oceans.

Sea water is a unique solution with a very small quantity of everything dissolved in it. Scientists have already detected more than fifty elements in sea water including such valuable metals as gold, silver, copper, magnesium, etc. Several costly chemicals and useful salts and miracle drugs can also be obtained from the sea. The sea can provide us with electricity and endless quantities of excellent drinking water. The sea is also a huge reservoir and transformer of the heat of the Sun and an effective stabilizer of the world's climate. It can cause wet or dry, hot or cold, good or bad weather.

That the sea can be considered as our mother from the astonishing fact that the very blood that flows through our veins is a solution very similar to sea water.

Beneath the waves, beyond our vision, is the ocean floor. In some places it is a vast undulating plain. There are tall mountain ranges, wide valleys, gaping canyons and deep, dark trenches. In the shallow waters of the tropics, there exist under-water coral gardens which remind us of a fairy land of exquisite beauty.

Huge warm or cold rivers called currents flow gently through the oceans, tides rise and fall in recurrent rhythm and under-water volcanoes explode creating devastating tidal waves.

In some regions, furious winds known as cyclones, typhoons or hurricanes roar over the oceans, but there are also regions that are silent and still as if forgotten by the winds

The majesty and mystery of the oceans have always fascinated man and will continue to do so. Man becomes weak, helpless and small when he faces the mighty sea. Her power and savage force create in him feelings of awe and mystery, her enchanting beauty intoxicates his imagination, her secrets turn him into a curious scientist and the hidden resources give him opportunities for limitless exploration and profitable exploitation

Let us discover some facts about this world of water we call the oceans.

In recent years there has been a great interest in the study of the oceans. This is particularly true of India when a multi-nation survey of the Indian Ocean is in progress at present. Several aspects of the Indian Ocean are being studied in great detail Therefore, it has become essential that at least an outline information about the oceans in general and the important results of recent scientific studies be placed before everyone in a language which is clear and easy to understand. Such an attempt, it is hoped, would help to clarify the real significance and importance of oceanic research and will help the school students to know some fundamentals of marine biology. It is greatly hoped that the matter presented here would be easy to understand, for it is written in a simple and non-technical language.

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ACKNOWLEDGEMENTS

The National Council of Educational Research and Training wishes to acknowledge with appreciation the readiness with which Prof. N. Balakrishnan Nair, the author, agreed to our suggestions and the trouble he took in preparing this book; the help rendered by Shri S. Doraiswami of the Department of Science Education who has examined the manuscript critically and made several observations which were agreed upon by the author; and the constant vigil and attention shown by Shri K J. Khurana of the Department of Science Education in seeing the publication through the press.

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Chapter 1

Introduction

The beginning

THE EXACT ORIGIN of the Sun, the Earth and its companion planets that form the solar system is not clearly known. Nobody was there to see this very important event. Evidences regarding the origin and the early history of the universe are extremely meagre. Whatever little we know about the cosmic birth is based purely on speculations. Here it is unnecessary to go into the details of the various suggestions about this unknown event.

First of all we have to imagine the conditions about five billion years ago. Then probably there was only the black, endless space with practically nothing in it except for some cosmic dust and gas. These drifted passively in the cold, silent space. Time passed on and on and the drifting particles of dust and gas gathered into large shapeless clouds. Gravitational pull attracted these scattered particles in each cloud towards its centre and made them more and more compact. Thus, step by step the formless clouds began to shrink into clusters and to spin round and round. As a result of the spinning force the bits of matter in these clusters collided and crashed and eventually got packed together. In this mechanical process of crashing, crowding and close packing of the particles, a great amount of heat was generated especially within the centre of each cluster.

They became red hot and began to glow. In this manner countless numbers of stars began to shine in the icy emptiness of space and there was light in the darkness.

The birth of the Sun

One of the rapidly whirling, blazing clouds became the Sun. As a result of a great storm, rushing streams of gases flew out and this cloud began to spin at a very great speed. The particles and gases in it were packed into a gigantic sphere of glowing gases. The Sun is a brilliant star about 1,390,000 km in diameter. From the Earth, the Sun appears to blaze in a blue sky. This is owing to the presence of an atmosphere around us. But for this, the daytime sky would be black. The particles in the atmosphere scatter the sunlight waves, having wave length of blue colour and thereby impart a blue colour to the sky. Though the Sun is 150 million km away, it is still much nearer to us than any other star. It is on account of this nearness that the Sun appears bigger and brighter than other stars. Within the substance of the Sun, fastly moving hydrogen atoms constantly collide and fuse together to form helium, releasing enormous quantities of energy. This energy radiates into space as sunlight, etc. While the Earth is a solid mass, this great star is in reality a glowing atomic furnace weighing 3,303,000 times more than the Earth. Like the Earth, the Sun also rotates from west to east but takes 27 days to complete one turn whereas the Earth completes it in 24 hours which we call a day.

The birth of the planets

Some of the clouds of gas and the cosmic dust trailed around the Sun. Some believe that a part broke up and turned into whirl-

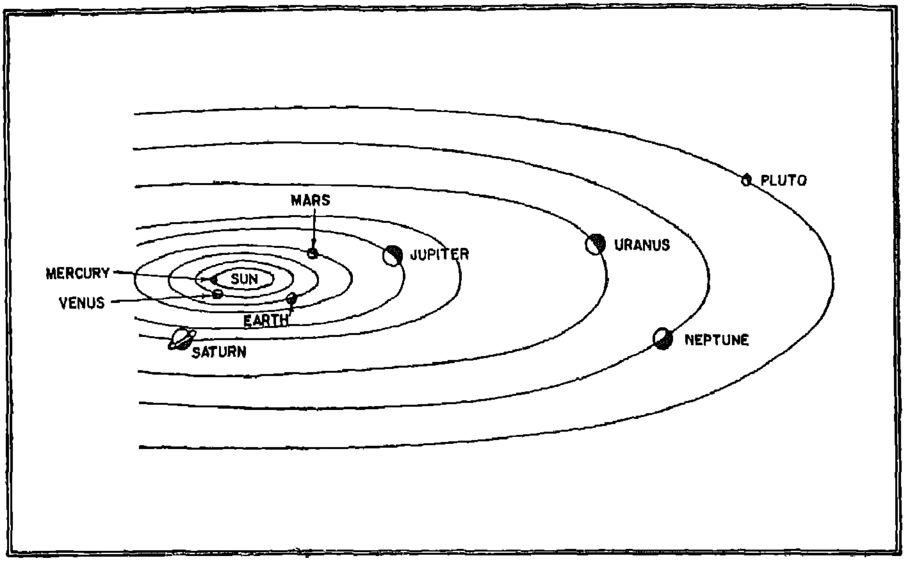

FIG. 1. The Sun and the planets.

pools. Each whirlpool circled the Sun in its own path, some near the Sun, others far away. Those near the Sun were hot and those farther away were cold. In each whirlpool, dust and gas went round and round. Some of them formed water vapour which settled on the dust as dew. When dust particles met, they were pasted together by the dew and grew into larger and larger bodies and later large rotating balls were formed which finally became the planets. The word planet means wanderer. Out of the whirlpools nine planets were formed. Each planet travelled on its own path around the Sun. Mercury was nearest the Sun. Then came Venus, Earth and Mars. Beyond Mars, circled Jupiter, Saturn, Uranus and Neptune. Far beyond Neptune was Pluto. Of the nine planets four are larger than the Earth, three are smaller and one, Venus, is much the same size. The Sun forms the centre of the planetary system. Like the Earth the other planets also revolve round the Sun from west to east. The planets remain in their respective orbits on account of the Sun's pull or gravitational attraction. This prevents them from rushing into space. The Sun and its planets are located near the rim of the Milky Way and are insignificant when seen in the vastness of space. The planets have no light of their own. They just reflect the sunlight. The Sun shines on all the planets. On the Earth, as on every planet, night follows day and day follows night. Because of the rotation some part of the planet is always turning away from the Sun and beginning its night. Some part is always turning towards the Sun and beginning its day.

Of all the planets in the solar system, Mercury is the smallest and is the one nearest the Sun. Its closeness to the Sun makes it a very hot planet for the existence of any life on it. It takes 88 days to complete one cycle round the Sun, during which time it rotates once on its axis. Since this planet rises and sets with the Sun it is not visible to us. Situated 108 million km away from the Sun is Venus, a planet resembling Earth though a little smaller in size. Venus takes 225 days to complete one revolution round the Sun. This bright planet is visible both in the morning and in the evening. The atmosphere of Venus is dry and contains carbon dioxide and is surrounded by a veil of white clouds. The third planet from the Sun is Earth and after Earth is the interesting red planet Mars. The nearest distance between Earth and Mars is 55 million km and its distance from the Sun is about 225 million km. Though the green patches on Mars are believed by some to be vegetation, it is doubtful whether any life exists there owing to the fact that there is practically no oxygen in its atmosphere to maintain life. With a diameter of

6,900 km, Mars is one-tenth of the Earth in weight and takes 687 days for one circuit round the Sun. This planet completes one rotation in 24 hours and 37 minutes. Jupiter, 1,300 times the size of the Earth, is the biggest planet in the solar system and is 777 million km away from the Sun. It takes 12 years to complete one cycle round the Sun. Twelve moons shine over this cold planet and its atmosphere contains plenty of hydrogen and helium and also methane and ammonia. Saturn, 1,425 million km away from the Sun, is slightly smaller than Jupiter and has 9 moons and takes $29\frac{1}{2}$ years to complete one revolution round the Sun. Uranus and Neptune are situated 2,896 and 4,505 million km, respectively away from the Sun. These are nearly fifteen times heavier than Earth. Uranus has five moons and Neptune has two. Pluto, discovered only in 1930, is a very cold planet situated 5,953 million km away from the Sun and takes 248 years to complete its journey round the Sun. Its exact size is not clearly known.

In the early phase of the Earth's history, the Sun blazed in a black sky. In the darkness around the Sun stars twinkled. The daytime sky was black because there was no air, as there is now, to catch the sunlight and make the sky look blue.

The birth of the Earth

Scientists think that about three billion years ago our Earth was in the form of a very hot ball of whirling gases. These gases gradually got compressed to form a red hot ball of molten rock. There were terrific explosions which sent hissing clouds of steam into the sky. Gradually, the materials of the mass cooled and then sorted themselves out according to their weight and they were arranged as follows. The heaviest matter sank to the centre, the less heavy surrounded it and the lightest rose to the surface forming the outer part. Even now the centre of the Earth is a ball of molten iron 7,240 km across with a temperature of about 2,760°C. Around it is a middle layer, not fully hardened, about 2,900 km in thickness made up of a thick grey-green iron-rich rock. Covering it, there is a comparatively thin layer about 16 to 32 km thick, like the skin of an orange, made up of black rock composed of basalt and granite. Slowly, the outer crust cooled sealing the fiery heat in the centre of the Earth. All this time it was spinning like a top describing an elliptical orbit round the Sun, its parent. Among all the planets of the solar system, Earth is very likely the only one inhabited by living things because it receives just enough light and warmth. It is the most diversified, the most changeable and the most picturesque. No other planet has the oceans, the blue skies patched with lovely clouds, flaming sunrises and glorious sunsets, beautiful rainbows, rains, rushing rivers and the lush green vegetation.

The birth of the Moon

It took many millions of years for the Earth to change from its molten state to the present solid state. Before this cooling, another very great event took place. That was the birth of the Moon. A part of the molten spinning Earth was torn off and whirled into space probably from the part which is now the Pacific Ocean and this remained near the Earth as the Moon. Cracks developed on the Earth's crust owing to the shock which the Earth experienced at the birth of the Moon. Parts of the crust began to shift. This resulted in the formation of two large gaps. Two oceans, the Atlantic and the Indian, arose in these gaps. So really the Moon is a child of the Earth and its attraction causes the tides in the oceans.

The distance that separates Moon from Earth is nearly 3,86,240 km.

From the hot masses in the centre of the Earth great jets of water vapour, carbon dioxide and other gases escaped and spread around it and formed a thick blanket of air. Thus was formed the Earth's atmosphere. The water vapour gathered into clouds. These clouds were so thick that no light could pass through it. So the Earth was in total darkness. When the clouds cooled, the first rains fell.

The birth of the oceans

When the first rains fell, they simply boiled off and rose up again as steam because the earth was still a very hot ball of rock. So, naturally, there were no rivers, lakes or oceans. There were neither plants nor animals. The rains fell on the hot barren rocks and hissed up as steam. The lifeless earth reeled round and round through the icy emptiness of space. In some places the rock melted and thick hot lava flowed out and the sky was full of steam. There were thunder storms, and lightning flashed across the sky very often. Deafening roars of thunder could be heard all the time. White, hot, blindingly bright stars rushed through the steaming air and struck the Earth. It was an infernal landscape, had any one been there to see it. But no living being could exist in that hot airless steamy Earth.

As time passed and the Earth cooled, more and more water fell as rain, continuously, ceaselessly, day and night. The days passed into months, into years, into centuries and millenniums, but the rains continued to fall. It was a terrible deluge. These waters rushed down the rugged, rocky Earth into the vast depressions and basins. The pools and ponds became lakes, shallow seas and eventually deep oceans. The dark clouds gradually thinned, permitting the sunlight to pass through, and then the oceans glittered under the brilliant sunshine. The primitive ocean was not as salty as it is now. As time passed, the rain water carried with it the soluble minerals of the Earth and the salts and drained them into the seas. About 26,650 cu km of water containing dissolved substances flow into the seas every year. This process went on ever since the rains began and the sea grew bitter and bitter with the salt carried down the continents by the rains and rivers. Mount Everest, the tallest mountain on Earth, is 8,825 metres high and if it were placed in the deepest part of the sea its peak would be covered by about 2 km of water! The floor of the sea is in some regions pitted by volcanoes some of which are still active.

The birth of mountains

The cooling of the hot earth was a very violent process. During this process of shrinking, the earth's surface wrinkled up like the skin of a dried date fruit with folds and furrows. Cracks and crags as well as bulges and basins appeared leaving the surface uneven as we see it now. The crags and bulges became the mountains and the cracks and basins formed the valleys, the seas and the oceans.

Our Earth is not standing still. It is a big ball of rock about 12,875 km in diameter spinning on its own axis like a top at a speed of 1,600 km an hour at the equator. It makes one complete turn from west to east every 24 hours. It is revolving in an oval path around the Sun at 32 km per second. Even at this great speed the Earth takes a little more than 365 days to circle the Sun completely. We call this length of time a year. As it whirls, it holds us all to it with a strong pull called gravity. The Earth is surrounded by an atmosphere of some 805 km but within this planetary mass living things can thrive only within a small zone of life called the biosphere. On land, this zone extends only a few feet beneath the earth's surface. In the air, life can exist only in the lower layer of the atmosphere. As we go higher and higher, the air becomes too thin for the existence of any life. In the sea, there is life almost everywhere even in the greatest known depths. but the number of animals decreases greatly with the depth. This biosphere is only about 24 km thick. However, within this narrow belt there is an amazing variety of life, in the air, on land, in the fresh waters and in the sea. Our Earth is only a tiny speck in the universe. But it has special properties that are very rare in the universe. The universe has stars as hot as 19,444,427°C. It has also empty space as cold as –262·8°C. The Earth has just the right

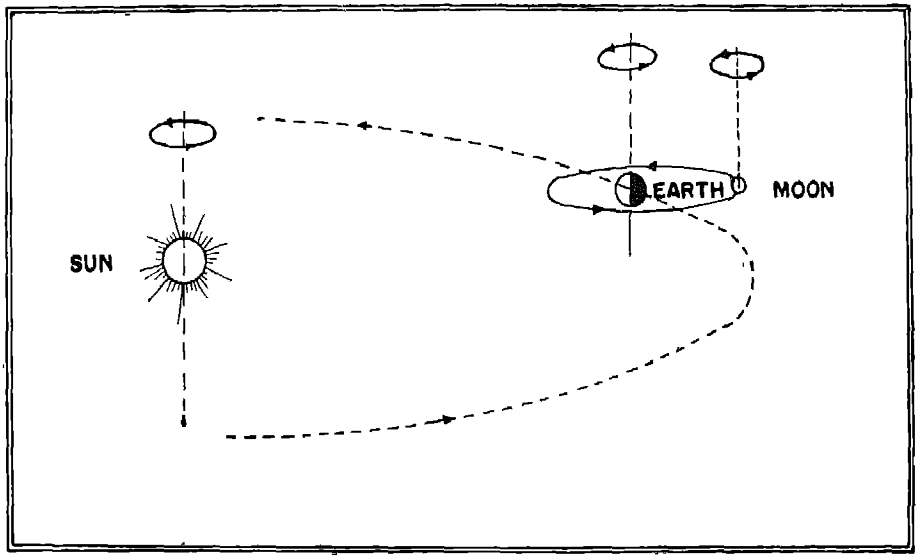

FIG. 2. The motions of the Sun, the Earth and the Moon.

temperature for rare and delicate forms such as living things, the plants and the animals.

The birth of life on the Earth

Our planet lay barren and lifeless for a very long period of its early history. Perhaps four billion years ago, in the warm waters of the early seas, a wonderful substance appeared in a manner unknown to us today. Tiny bits of matter that could be called living came into being. This might have been created by the action of sunlight upon the chemicals in the warm seas. Life was created from materials that were lifeless. These little specks of matter with the mysterious spark of life were probably like the viruses of today, simple chains of atoms that form molecules.

From these simple specks of living matter, which were the beginnings of life, there began to emerge the endless stream of living things we know, the crawling, swimming, walking and flying forms of animals and the countless herbs, shrubs and trees. The first living things were a group which was neither plants nor animals. They represent the border line between the non-living and the living. These first children of the sea lived on minerals present around them. As time passed and the thick layer of clouds that covered the Earth became thinner and thinner, the Sun began to shine brightly over the Earth. Some of the early forms of life developed the wonderful green substance called chlorophyll. This magic substance in the presence of sunlight can synthesize food in the form of sugars from such easily available simple substances as carbon dioxide and water. Thus a group of tiny living things with green colour came into being capable of preparing their own food. These were the first plants. Another group of living things without the green chlorophyll began to make use of the plants by eating them and these became the animals. Directly or indirectly all animals on Earth depend on the green plants for their food.

The evolution of life on the Earth

Years passed on and on. The simple forms of life became more and more complex. The first creatures were single cells. Later others arose that were collections of cells. Still later evolved creatures with a head and tail, definite organs for feeding, digesting, breathing, reproducing, etc. Sponges and corals grew out of the sea floor, worms crawled on the ocean floor, and fishes of different kinds swam in the wide expanse of the oceans. Plants too progressed from simple forms to more and more complex types.

But the dry land still had no living things on it. It was just a mass of barren rocks, which was undergoing slow cooling. The outer layers cooled first. This was followed by the cooling and contraction of the interior masses which drew away from the outer shells. So the shell was now too big and in order to fit the shrinking Earth, the crest fell into folds and wrinkles which caused the formation of mountain ranges as stated already.

There was still no plant cover for the continents and they lay desolate, barren, silent and lifeless. In the sea, life was flourishing and evolving in different directions. About 350 million years ago, the first pioneer of land life crept on the shore. This was an ancestor of the crabs and insects of today, a scorpion-like creature living partly on land and partly in water.

Fish began to appear in the seas, rivers and ponds. When the water in the rivers and pools became foul, some fish developed special devices to store air in small bladder-like structures and even to crawl out on dry land. Owing to the crumbling of rocks, soil began to form on the surface. Some of the hardy varieties of sea weeds found it possible to survive on the coastal areas on land. Some of the fishes also developed special methods to remain out of water for some time and later developed lungs to breathe atmospheric air as we do. The first land vertebrates were the ancestors of the present day frogs and toads.

On land, mosses and ferns and the seed plants developed. The land animals began to move far inwards from the edge of the water. They developed thick outer coats for the body and evolved an egg that could be laid on dry land. Thus they bid good-bye to their original home, namely water, and became typical land animals. These forms were the relatives of the present day lizards, crocodiles, turtles and snakes. Some of these were formidable lizards. In course of time, some developed feathers from the scale covering and with the help of wings, which are modified front limbs, took to air to become the birds. Another group developed hair as a cover for the body and instead of laying eggs specialized in giving birth to live young ones and to feed them on milk from special glands. These are the mammals of which class we, human being, are members. Some land animals later returned to the sea like the turtles, sea-snakes, the whales, etc.

Among land animals, some became good runners, others turned to become good climbers, while a few specialized to be burrowing forms. Man is descended from a group of tree-dwelling creatures. His ancestors came down from trees and began to use the hands for many useful purposes. He has tamed the fire, invented the wheel and has brought nature almost under his control. He represents the end of a tall ladder, the first step of which was the living substance formed in the tepid waters of the ancient seas.

Chapter 2

This Watery World

Do YOU KNOW that the most conspicuous part of our planet is the sea? If you look at the Earth from space you may well name our planet sea rather than Earth. The reason for this unique feature is that water covers nearly 71 per cent of the surface of the globe. If so, only about 29 per cent of the Earth's crust shows above water and the rest is under water. Thus it is a watery world on which we live. The Pacific Ocean alone has a bigger area than all the five continents. The continents of the Earth actually are only islands in the great body of water, namely the oceans. Therefore, it will not be incorrect to say that our Earth is nearly drowned in sea water. Scientists have calculated that the oceans contain about 1,333 million cu km of water!

This great connected sheet of water which covers the greater part of the Earth's surface is called the ocean. The Babylonians thought that the world was a great mountain rising from the midst of a universal expanse of water. The Hebrew scriptures state that the waters were gathered together in one place at God's command and dry land appeared. The Greeks believed that the disc of the world is surrounded by a powerful stream named Oceanus (Okeanos) the name of primeval God, father of gods and men. So the ocean was considered as the bond of union between heaven and Earth.

Oceans

It is rather difficult to get an idea of the great size of the oceans by looking at the sea from the sea shore. If you are lucky to go on a long voyage you will soon be amazed by what you see. Everywhere you see nothing but water. Endless stretches of wavy, rippling, restless, blue-green water will be seen all around and you will get a feeling of loneliness as if you are in a desert with no trees and no visible signs of life. You can sail for days and cross hundreds of miles of water before sighting land. You may be surprised to know that the total weight of the world's waters has also been calculated by scientists. It amounts to one - and - a - half million, million million tonnes. The average depth of the world's oceans has been calculated at roughly four kilometres.

Look at the map of the world and try to compare the proportion of the land and the water. You will be able to realize how big the ocean really is and that much more space is covered by the ocean than by the land. Now that you are looking at the map let us at once locate the oceans of the world. You will have no difficulty to find out the Pacific, the Atlantic and the Indian Oceans. See the Arctic Ocean on the upper side of the map and the Antarctic on the lower side. You will notice that the Antarctic Ocean has no distinct boundaries of its own. These are the five oceans of the world, extending for thousands of km each flowing freely into the other without any national boundaries. The Pacific is by far the largest of them all.

The areas of the five oceans and their average depths are given as follows:

	Area in square kilometres	*Average depth in metres*
Pacific	177,597,900	4,282
Atlantic	105,229,916	3,916
Indian	74,049,290	3,953
Arctic	13,926,904	1,205
Antarctic	No fixed boundaries	

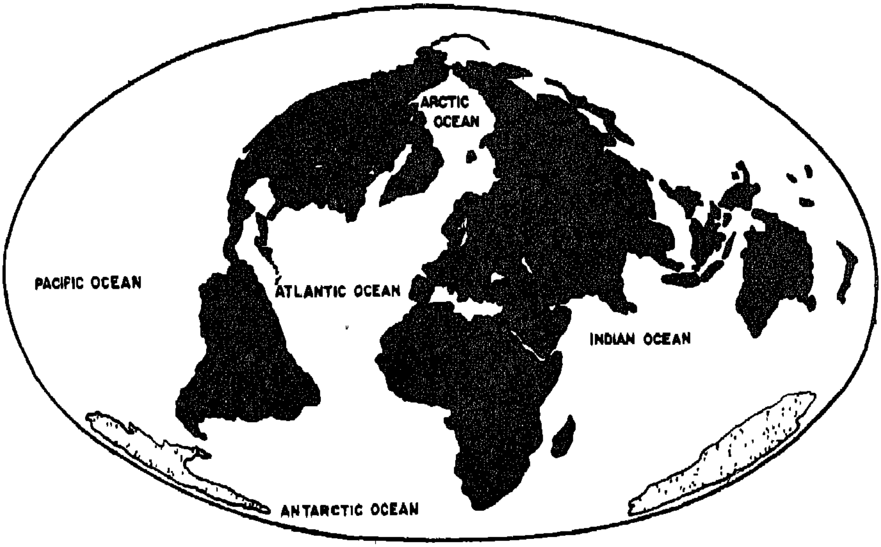

FIG. 3. The continents of the Earth actually are only islands in the great body of water

Some divide the oceans into 'seven seas'. They get this seven by dividing both the Atlantic and the Pacific into two parts each, naming those areas above the equator North Atlantic and North Pacific and the parts below the equator South Atlantic and South Pacific. Then the Indian Ocean, the Arctic and the Antarctic make seven oceans in all. These numbers are really artificial. It can as well be just one, for the whole ocean is a single connected body of water.

Sea, gulf and bay

You may be wondering what is the difference between the oceans and the seas. As stated already the name ocean is given to the five great stretches of water that we have already named. Seas are bodies of water which are mere extensions of the oceans. These are sometimes separated from the oceans by projections from the mainland or islands. The Mediterranean Sea between Europe and Africa and the Arabian Sea which is an extension of the Indian Ocean between Arabia and India are good examples. The names, bay and gulf are given to portions of the oceans that extend far into the land. Look at the map and see the Bay of Bengal and the Gulf of Aden.

The colour of the sea

We imagine that the sea is blue or green. This may perhaps be due to the fact that this area is marked blue in maps. But it is a fact that it takes other colours also. The usual colour of the oceans is green when the water is not very deep. It takes a lovely blue, grey or even intense green when the water is very deep. The blue colour is due to scattering of light by water molecules. The colour of the sea depends also on the nature of the day, whether there is bright sunshine or not at the time you are looking. Sometimes the colour of the sea water may be due to the suspended particles in it, or due to the presence of countless numbers of tiny coloured animals living in the water, or due to plants present there. It may also be due to silt brought into the sea by rivers. Thus the Red

Sea and the Yellow Sea get their names from the apparent colours of their waters. The Red Sea is said to get its colour from the countless numbers of minute algae which live a floating life in its waters. The colour of the Yellow Sea near China is due to the fine particles of clay which are carried into it by the rivers.

Salts in the sea

We have noted in an earlier section that the oceans in the beginning have been only faintly salty. As the rains fell through the ages the lands began to be worn away. The minerals present in the rocks got dissolved in the rushing waters and finally reached the ocean. This one-way, non-stop flow of minerals from the land to the sea has been going on through the cycle of rain and rivers, and as time passed on and on, the sea became more and more bitter on account of the salts drained into it from the continents. Now there is enough salt in all the oceans to build a mountain higher than any on land. Some seas are saltier than others. The Red Sea for instance which lies between the hot deserts of Africa and Arabia is the saltiest sea. If you were to swim in it you would find it difficult to dive to the bottom. The reason for this is that the more salt there is in water, the more weight it can hold up. If you want to try the truth of this statement, here is a simple experiment which you can do at home. Fill a glass vessel with fresh water and place an egg in it. If the egg is a good one it will sink to the bottom. Now go on adding powdered salt into the water and you will soon find that the egg is floating! Of all the oceans, the Atlantic is the saltiest. The polar seas are the least salty on account of the melting ice, rain and snow.

The nature of sea water

Water in general has many special properties. All living beings, the weather, soil, etc. depend on water. Water has the capacity to store great quantities of heat. So, great bodies of water like the oceans are huge reservoirs of heat which they receive from the Sun. This helps to keep the climate moderate along the shores of the oceans.

We all know that sea water is saltish to taste. In the open ocean the salt content is fairly uniform except at its uppermost layers soon after rains. This is because rain water will float over the sea water. Close to the shores and near the mouths of rivers the salt content will be much less on account of the fresh water of the rains and rivers which would dilute the sea water. It has been calculated that 454 kg of sea water will contain between 13 and 18 kg of salts. Of these about 12 kg will be common salt (sodium chloride). Other salts present in sea water in fair quantities are magnesium chloride, magnesium sulphate, calcium sulphate, potassium sulphate, calcium carbonate and magnesium bromate.

Minerals in sea water

So, it is extremely wrong if you think that sea water contains only common salt. The truth is that a very small quantity of everything is dissolved in it. This is because water in general is a very good solvent. Every drop of water that falls down as rain takes up an extremely small quantity of minerals. The rain water collects together, forms rivulets and then rivers and at last reaches the ocean. After reaching the sea, the water is again lifted up into the air by evaporation by the wind and sun to form the clouds. But it leaves behind a great quantity of minerals in the sea. Again, the clouds burst into rains and the process is repeated. It has been calculated that each year some 333,000 cubic kilometres of sea water are lifted in this manner into the atmosphere and again returned to the land and sea as rain. For this process nearly one-fourth of the sun's energy that falls over the Earth is utilized. The drops of water that fall on Earth act like little vehicles carrying minerals from the land into the sea leaving the oceans a great store-house of minerals. Thus centuries by centuries through this one-way flow of minerals into the sea, the stock in father Neptune's chemist's shop has grown bigger and bigger and the salt water has grown denser and denser. From this it is easy to understand that one can find traces of every

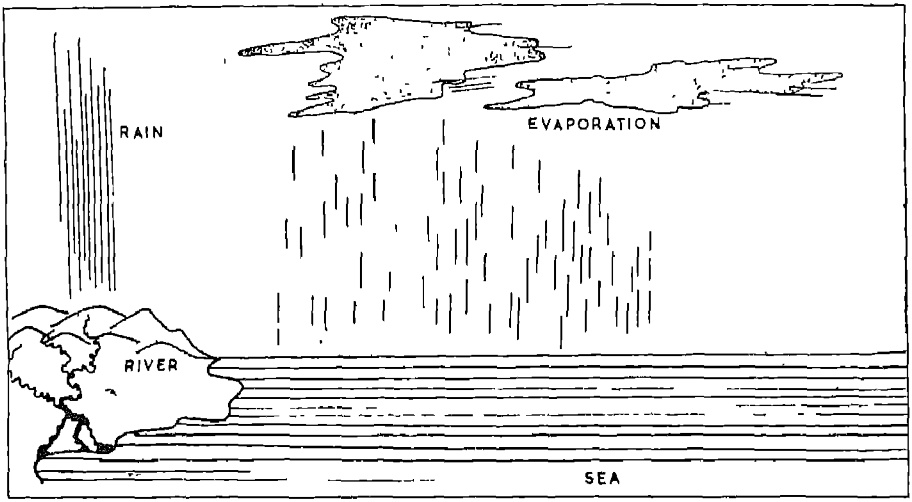

FIG. 4 The water cycle. Each year nearly 333,000 cubic kilometres of sea water are lifted into the atmosphere and again returned to the land and sea as rain For this process nearly one-fourth of the Sun's energy that falls on the Earth is utilized.

chemical in the ocean. Scientists have already detected the presence of more than 50 elements by special techniques and chemical analyses. The difficulty in detecting all the chemicals and elements in sea water is that they are present only in minute traces and our methods are not sensitive enough to detect their presence at present. By using better methods it may be possible for scientists to make a complete analysis of the sea water.

It is interesting to note that many organisms living in the sea have the unusual ability to absorb and retain within their bodies various elements, some of which are found only in very small quantities in the sea water. Thus the sulphur bacteria can absorb sulphur, the single-celled radiolarians absorb strontium, the algae and sponges contain iodine, certain sea weeds, aluminium, the jelly fish, zinc, tin and lead, the molluscs and crustaceans absorb copper and the sea-squirts, vanadium.

It has been found that a cubic km of the sea water has about 1 kg of gold. Therefore, if the earth has about 1,353,000,000 cu km of sea water the calculation is that it contains nearly 1,360,800,000 kg of gold ! From this you can imagine that the sea is a reservoir of this precious metal. Unfortunately, it is very difficult to separate this gold from the water. For example, to get sufficient gold for one sovereign it is necessary to treat chemically over 100 tonnes of sea water. This is indeed a very difficult and costly process. A German scientist Fritz Haber, who tried to extract gold from sea water realized with sadness that the cost for the extraction was much more than the gold produced. Fourty-four elements that are present in detectable quantities in the sea water are given below in the order of the amount of each dissolved in sea water.

1. Chlorine
2. Sodium
3. Magnesium
4. Sulphur
5. Calcium
6. Potassium
7. Bromine
8. Carbon
9. Strontium
10. Boron
11. Silicon
12. Fluorine
13. Nitrogen
14. Aluminium
15. Rubidium
16. Lithium
17. Phosphorus
18. Barium
19. Iodine
20. Arsenic
21. Iron
22. Manganese
23. Copper
24. Zinc
25. Lead
26. Selenium
27. Cesium
28. Uranium
29. Molybdenum
30. Thorium
31. Cerium
32. Silver
33. Vanadium
34. Lanthanum
35. Yttrium
36. Nickel
37. Scandium
38. Mercury
39. Gold
40. Radium
41. Cadmium
42. Chromium
43. Cobalt
44. Tin

Some of these elements are very essential for the life and growth of plants and animals. For example, calcium is essential for animals like the snails clams and corals for their shells and skeletons respectively. These creatures remove the lime from the sea and build them into their shell material or skeletons. Countless numbers of these creatures are thus removing thousands of tons of calcium from the sea water every day. The shells of dead animals settle to the bottom and become limestone. Fresh supply of calcium to the sea comes from the calcium that is drained by the rivers into the sea. Similarly, silica is required by the tiny plants called diatoms to make their glassy shells and large quantities brought down by rivers are used up by these from the sea water.

Chapter 3

Movements of the Sea Water

THE WATER IN the oceans is restless at all its levels. It always exhibits some kind of movement in the form of tides, waves or currents. These movements are caused by the winds, the rotation of the Earth, changes in the density of the water and the attraction of the Moon and the Sun. The surface waters move mainly owing to the action of the winds.

If you stay in the beach for a few hours you will soon find that the sea shore is either growing wider or narrower. If it is growing wider it means that the tide is going out. The tides of the oceans are always rising or falling. When the tide is rising you can see that each wave comes a little farther inland than the one before. When it is falling you will notice that the waves are not coming as far into the beach as they did a few hours earlier. This is due to a regular movement of the sea called the tides. Tides are regular rise and fall of the ocean level. This usually takes place twice every twenty-four hours. That means there will be two high tides and two low tides each day. But there are certain shores where there is only one in every 24 hours. This happens in a locality called Northern Sound in Alaska and in certain parts of the Gulf of Mexico. For many hours at a time the water rises covering the beach until it stops without any rise. This rising of the water is called the

‘ flood tide’. The highest water level is called the ‘high tide’. After reaching the greatest height the water level goes down gradually, leaving the shore exposed. Now the tide is said to ebb until it reaches its lowest point called the ‘low tide’. The incoming water during the high tide is called the ‘flow’ and the outgoing water is known as the ‘ebb’. High tide and low tide follow each other in regular cycles.

The real cause for this rise and fall of the sea level was not known to men for a very long time. Some imagined that Earth itself was alive and the rising and falling of the tide, they thought, was caused by the breathing of the Earth’s big body. As time passed and knowledge increased, men began to learn more about the heavens and the stars and the planets. This helped them to understand the tides of the sea. They found out that the Moon is a satellite and it travels a regular path around the Earth. They noticed that the Moon rose each day about an hour later than it rose the day before and the peak of the high tide also comes about an hour later each day. So they concluded that the Moon and the tide are connected in some way. It was Sir Isaac Newton who first explained the secret behind the tides. Newton worked out the famous theory of gravitation. According to him gravity is the power possessed by every object in the universe to attract or pull towards itself all other objects. The bigger and closer an object, the more powerful, is its attractive pull. For example, the Earth pulls every object towards it. That is why a mango falls down to the Earth. It is the same force of gravitation that keeps all of us and the objects around us from flying off into space as the Earth is fast rotating. The objects on the Earth also feel the pull of the Moon and the Sun. But since the Sun is far away its pull is only one-third of that of the Moon in spite of the fact that it is 27 million times as big as the Moon. The Moon is then the main factor that causes the tides in the oceans. This is because while the gravitational pull is proportional to the mass of the attracting body, the force diminishes in proportion to the square of the distance.

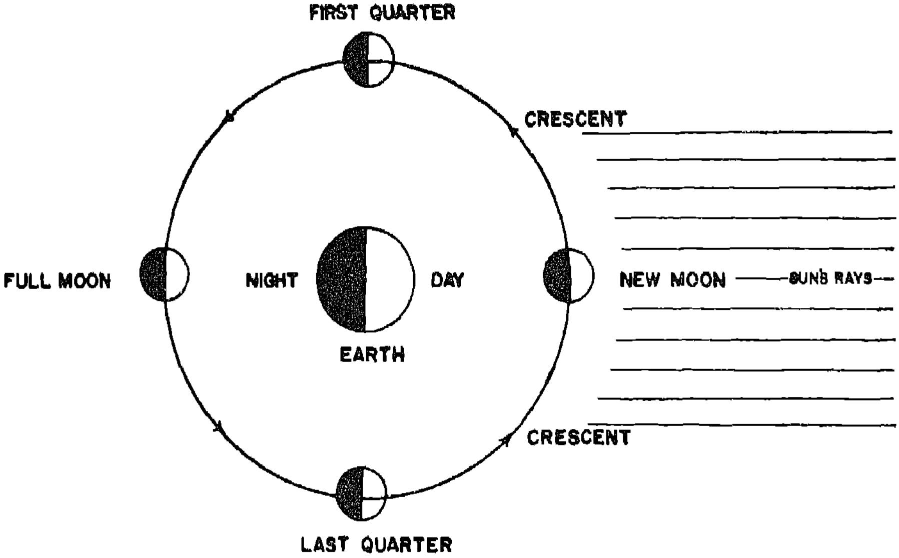

FIG. 5 The phases of the Moon.

So, it is evident that the tides are caused by the pull of the Moon and the Sun on the Earth. These heavenly bodies act like two huge and powerful magnets always pulling at the Earth. It is this force that makes the tides go higher or lower in the oceans. Every drop of water in the ocean from its surface to its deep floor responds to this invisible, mysterious, cosmic force. There is no other force that affects the sea so strongly. This pulling force is what is called gravitation. The distance between a given point on the surface of the Earth and the Moon is not always the same. Sometimes the Moon is closer than at other times and so the pulling force is stronger, creating a higher tide level. The result of this gravitational pull is that it raises up a part of the ocean. That raised water travels across the sea like a high wave as it approaches the shore. There it creeps up the sloping beaches, covers mud flats and marshes and lifts the level of the water of the bays, inlets and harbours. This is the rising tide. Sometimes the Sun and the Moon may pull from different directions with the Earth in the middle causing difference in tide levels. When the Sun, Moon and the Earth are all in a line, there is the combined force of the pull of both Sun and Moon. So, the swell of the water will be much more than usual. This makes an unusually high tide called the 'spring tide' which brings the water high on the beaches and boats float high beside the piers. This occurs two times each month during the new Moon and when the Moon is full. But when the line joining the Sun to the Earth is at right angles to those joining the Moon to the Earth, the pulling force of the Sun is opposite to that of the Moon. This produces an unusually low tide called the 'neap tide'. Neap tides occur twice a month when the Moon is at its first and third quarters.

If you look for high tides to occur at the same time every day you will not find them. This is because the time is governed by the relative positions of the Sun and the Earth and the tide by those of the Moon and Earth. The positions of the Moon and the Sun in relation to the Earth are not the same every day. As a result, the ebb and flow tides are about fifty minutes later each day which corresponds with the rising of the Moon.

The difference between high tide and low tide will determine the size of the tide. This size shows great variation in different

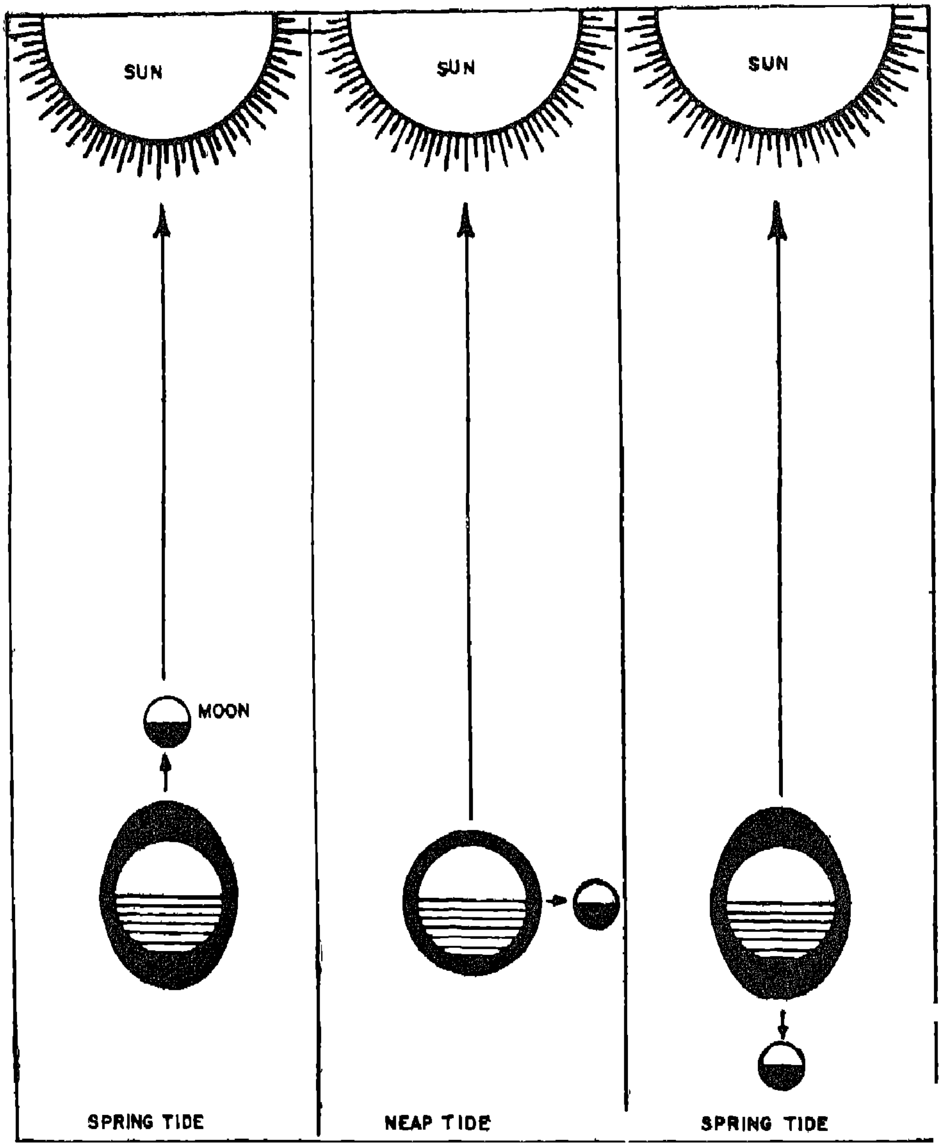

Fig. 6 The tides are caused by the pull of the Moon and the Sun on the Earth.

parts of the world depending on the land they touch. For example, on some islands in the middle of the great oceans there is hardly any tidal change at all. At the North Pole also same is the case. In the gulf of Mexico the water level rises only a few centimetres. In the Mediterranean Sea the water rises about a quarter or a half metre and at Cochin the rise is about one metre. Other parts of the world–parts of Australia, northern France and south west England–have tidal ranges of as much as 6 metres. The tidal range is more than 9 metres in the famous Bay of St. Malo in France. The nature of the tide is a local matter. Two places separated only by a short distance may show great differences in tide. Even though the Sun and the Moon set the water in motion by their pull, the height of the tide depends on local conditions such as the slope of the bottom and width of the entrance to the bay. On gently sloping sea coasts which are broad and straight the incoming tide has sufficient space to spread out. Therefore, the tidal rise will be small. On the other hand in places like a very narrow bay or channel the incoming tide will have very little room to spread and this will result in a rise of water level to a very great height. The Bay of Fundy in Nova Scotia, Canada is thus world famous for the highest known tides. This bay is shaped somewhat like a funnel and the tides must pass in through a very narrow inlet and so it forms the highest tides known in the world. The difference between high tide and low tide is nearly 16 metres. Scientists have estimated that the tide carries about 101 billion tonnes of water into the Bay two times every day. Just imagine how enormous are the masses of water the tide moves by its force. Scientists believe that the tides were much more powerful in the younger days of the Earth and their calculations show that the tides will slowly grow feebler until one day there will be no tides at all. The reason for this is that since the Moon was torn off the crust of the Earth, it was much closer to the Earth than it is at present. When it was half as far away, its power over the ocean tides was not twice, but eight times as great as now. The range between low tide and high tide may then have been several hundred feet on certain shores. The rising waters would cover the margins of the continents. But over the millions of years of its existence the Moon has moved away from the Earth and would continue to move away. So it will have less power over the tides and naturally they will grow weaker.

Tidal bore

A phenomenon associated with the tide is what is called a 'tidal bore'. This occurs with evil effects in some parts of the world. In this case the incoming tide rushes in like a huge wall of water through the narrow mouth of a river, toppling every thing on its path and destroying them. The highest tidal bore in the world is reported from Tsientang river. This river opens into the China Sea and during spring tides the tidal bore is fierce and forceful. It cruelly rolls into the river like a wall of death 7½ metres high, with a thundering roar at a speed of about 24 km an hour, causing destruction on its path. The tidal bore that sweeps up the Amazon river in South America is 4 to 5 metres high. It is so powerful that it travels up the river for nearly 320 km before disappearing. Its roaring noise can be heard over 8 km away. A wave nearly 2 metres high races up the river Hooghly.

Tide tables

There are special instruments with which it is possible to predict exactly at what time the tides will occur. Tide tables can thus be prepared in advance and they are available for use by those interested in this strange phenomenon of the oceans. These tables are very useful for fishermen and mariners. Captains of ocean liners use these tables to find out the best time to dock their ships or to make their way through a shallow area.

Waves

How beautiful it is to watch the sea from the shore on a calm day! How brazing is the soft, salty sea breeze as it sweeps over you leaving a salty film on your lips for you to taste! The steel coloured waves overlaid with a sheen of silver appear one after another at a distance from the shore and rush towards you. You can clearly see the wave toppling, curling and crashing and the water is hurled forward. Finally, it breaks up into salty, silvery spray and a cloud of foam below. Your feet get cool and wet with the foamy water. You feel the moving sand below your feet. This represents the final act in the life of a wave. The wave dies at your feet! Do you know where these waves come from?

In the sea, a wave is usually caused by the action of the wind on water. On calm days waves are gentle and small, on windy days they grow much larger, and on stormy days by the fierce energy of the wind they may become violent and rise to very great heights. As the wind blows over the smooth surface of the sea it causes the sea water to rise and fall in a regular rhythmic movement. It is easy to show how waves are born. If we take some water in a bowl and blow across the surface of the water the breath will make ripples. These ripples will move away from you over the water towards the other end. In the ocean such a ripple can grow into a big wave, if a strong wind pushes it steadily against their back over a long

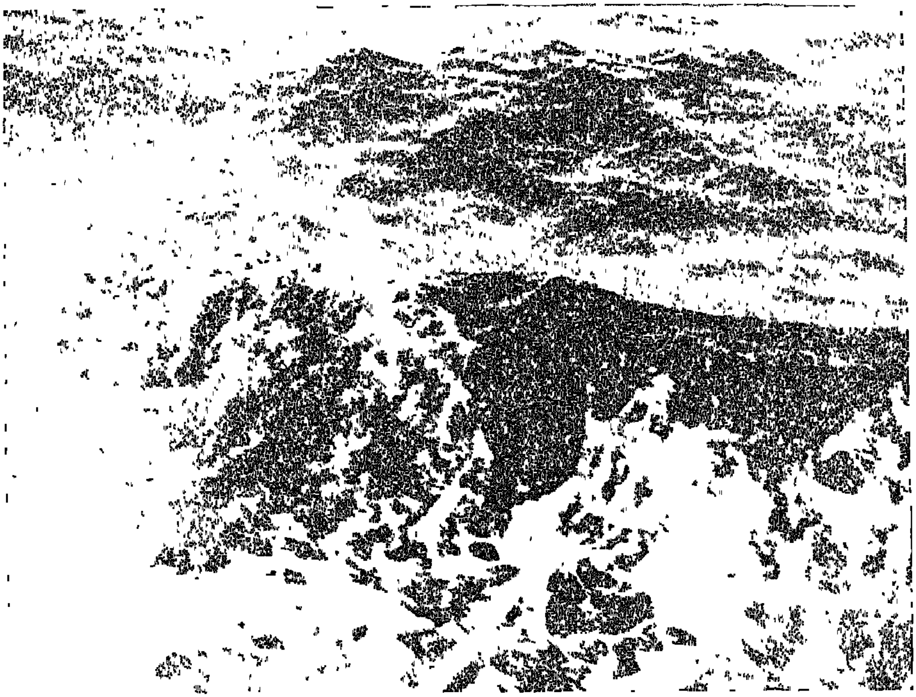

FIG. 7. Waves are caused by the action of wind on water.

stretch of water. The stronger the wind and the farther the wave can travel, the bigger the waves will be. The water is pushed into a series of ups and downs. The highest point to which the water rises is called the 'crest' of the wave. The lowest point to which falls is called the 'trough' of the wave. The height of the wave is the difference in level between the crest and its trough. Such a wave formed by the wind in the mid sea and then travelling out of the place of origin towards the shore is called a swell. The wave travels forward smoothly until it reaches shallow water. Here the speed of the crest exceeds that of the trough and eventually it overtakes the trough of the wave in front. The forward face of the wave will then be vertical and breaking occurs at this stage. The wave is slowed down only at the bottom but on the surface the wind still pushes it forward, driving the waves one after another towards the shore. Finally, they curl and rush ahead towards the land. These waves are called breakers and during their final rush they are called the 'surf'. The line along which the wave breaks is called the line of the breakers. If you have bathed in the sea you will easily know that beyond the breakers you can bob up and down on the water with very little forward motion. In the breakers you are pressed by the rushing waters which may knock you down and drive you towards the shore. The final size of the wave depends upon the speed of the wind, the length of the time it blows and also the miles of open water over which the wind blows in one direction. It has been calculated that to produce a wave 12 metres high, a wind speed of about 40 knots is required. A wave is more or less the up and down movement of the water particles. It is a fact that the many droplets of water that make up a wave do not move much forward normally with the wind; it is only the movement that passes onwards from ocean to the shore. A wave is not a moving wall of water advancing across the ocean to the shore. It is similar to the wind which causes

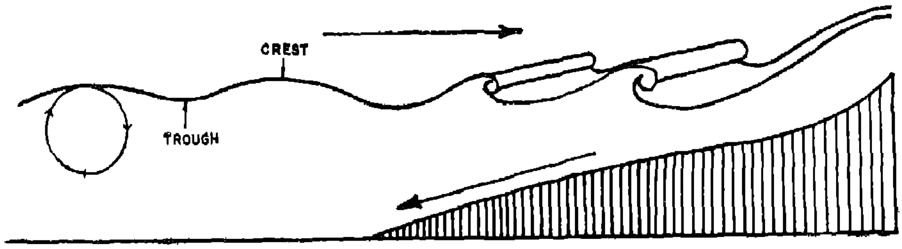

Fig. 8. Finally the waves curl and rush ahead towards the land.

ripples across a large paddy field without permanently moving the plants. It is also comparable to the passage of a wave through a rope. When a rope is snapped each part of the rope in its turn rises to a crest and then falls into a trough and wave passes through the rope. There is no doubt of the fact that every bit of the rope is in its original position in the rope. Each bit of the rope just rises and falls in a circular path while transferring its energy to the next bit of rope. Similarly, the wind moves the waves across the sea. So, the wave is just an invisible force. The water particles do not move up and down but swing in a spiral orbit, ending up at slightly forward of the place they started. This is the reason why a floating object like a cocoanut or a piece of timber beyond the breakers remains bobbing up and down without much movement as the wave appears to do. But during violent storms in the sea, the powerful winds can push the water ahead with great force and cause currents in addition to the waves which usually move up and down.

The breakers relentlessly and endlessly beat against the shore. They are responsible for the development and modification of shore lines along the sea front. The long stretches of white sandy beaches are created by wave action. The powerful and constant pounding of the breakers together with the grinding action of contained pebbles and sand weaken the foundation of rocky coasts and may even undermine lofty cliffs. In some areas, where the rocks are less resistant, the ceaseless and steady action of waves chisels off particles bit by bit and carves unusual caves and curious arches that form natural bridges. During the monsoon period along wide stretches of the west coast of India the south west winds whip up powerful waves. These waves smash in and mercilessly gnaw off into the sea edges of the land. Along with this erosion, valuable cocoanut palms are uprooted and houses are swept off and swallowed by the hungry seas. This coastal erosion has assumed serious magnitude in recent years and has become one of the major problems of the Kerala coast. The waves are thus aggressive in certain regions and move silently out with the fruits of their aggression year after year. In other regions the breakers scoop out sand from the sea floor and palyfully pile them up in the form of low, narrow offshore bars or Barrier Beaches parallel to shore lines. Between these offshore bars and the main land there will be a shallow area of calm water called the lagoon. In this case the waves add land to shore lines. The activity of breakers has built even islands in certain places. In Holland dikes are built to keep the sea away from flooding the low-lying areas.

Storm waves

There are dreadful types of waves called storm waves. These are very powerful and can easily toss huge ships like toys. They can also bring about great destruction along the sea coasts as they roar and roll shoreward. Great storm waves may reach heights of 18 metres and waves over 30 metres high have been reported. Some of them may be more than 300 metres long and may race through the water at speeds up to 96 km an hour. Such waves can exert enormous pressure on objects on the shore and cause great damage. For example, a stone weighing nearly 73 tonnes and situated 6 metres above sea level was pushed 18 metres across rough rocks. Heavy stones have been thrown to a height of several feet and windows of light houses have been smashed by the fury of the waves. In Scotland a pier weighing 2,642 tonnes was carried away by storm waves. In France during a severe storm stones weighing nearly 3,175 kg were thrown over a wall 6 metres high. In 1931 in British Honduras a 2,032 tonne dredger was lifted from the sea and dropped squarely on the roof of the customs house. This will give you an idea of the enormous power of the waves.

Tidal waves or 'Tsunamis'

Though almost all waves are produced by the activity of winds, they can also be caused occasionally by tides, earthquakes and volcanic eruptions. A tidal wave is a gigantic and dangerous wave. These are caused by under-water earthquakes and volcanic eruptions in the sea floor. When the floor of the ocean cracks and sinks, a great mass of water slumps into the newly-formed pit. Soon it rebounds with tremendous force as a pressure wave. The madly swirling water gives birth to wild and devastating waves which move upward and outward. One after another these waves spread out in widening circles for thousands of km until they have covered a quarter of the Earth's circumference. Afterwards, they start converging towards the antipodal point of their source. 'Tsunamis' may attain speeds of 800 km per hour and roll on for thousands of km. While moving over the open sea 'Tsunamis' are not unusually

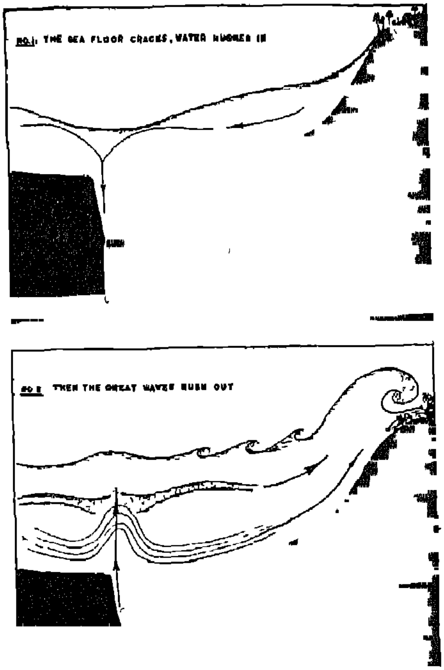
NO.1 THE SEA FLOOR CRACKS, WATER RUSHES IN
NO 2 THEN THE GREAT WAVES RUSH OUT

FIG 9. The tidal wave or 'Tsunamis'.

high; it is when they approach land that the waves swell up to great heights. Shortly before the great wave roars in, there will be a withdrawal of water from the shore. Places ordinarily covered by deep water could suddenly be exposed. The rushing water is very powerful to lift even heavy objects and throw them off. When the volcano Krakatoa erupted in 1883 it created one of the fiercest tidal waves on record. It was nearly 30 metres high and this swept across the Pacific at a speed of about 1,120 km an hour. Many towns in the neighbouring islands were completely destroyed and over 36,000 people were killed by this giant wave. One warship was bodily lifted up and left 3 km inland. In 1868 a United States warship was similarly carried a half of a km over the land by a large wave caused by an earthquake. On 10th November, 1932 a tidal wave 6 metres in height swept inland over Cuba. The cyclone which accompanied it had a velocity of 320 km an hour. Nearly 3,000 people were drowned, many towns were destroyed. From this you can imagine the power of the tidal waves and the destruction they are capable of bringing about.

A sensitive instrument called Vibrotron is used to detect, among other things, tsunamis and long waves caused by storm at sea. With this instrument it would be possible to detect such dangerous waves when the depth is quite large.

Kinds of waves

Waves are classified into two different kinds based on the type of motion which carries the movement forward. We have noted that the wave motion is only a transfer of energy from one place to another. The distance from crest to crest is known as the wave-length. The number of waves passing a fixed point in a given period is the frequency of the wave. The frequency multiplied by the wavelength would give the speed at which the wave is travelling. For example, if waves are about 30 metres apart and 4 of them pass a point every minute each wave is moving forward at a speed of 120 metres per minute.

A progressive wave· This is a wave that travels straight across the water from the place of origin to the other end. This is similar to the wave caused when you drop a stone in a tank. The breakers that we have studied are progressive waves.

A stationary wave: This is different from a progressive wave. Here the whole body of water is made to vibrate. To understand this type of wave take a rectangular tin half full of water. Now lift up one end and then drop it. The water would dash back and forth from end to end In the middle of the tin the water does not rise or fall. Here the wave does not travel like a progressive wave from one end to the other.

White caps· When the wind is blowing at great speeds, the tops of the tall waves are seen to be covered with white foamy spray. They are called white caps. These are formed when strong winds chop off the water from the crests of advancing waves. Such white caps can be seen in the open ocean as well as near the shore.

Ocean currents

Ocean currents are huge rivers of warm or cold water that flow silently through the oceans. Some are so large that the largest river in the world will look like a small stream in comparison. One current that flows through the Pacific from Panama to Philippines travels a distance of about 14,400 km. These currents flow along through definite courses at varying speeds. Some flow at a speed of about 8 km per hour. Ships sailing along these currents can, therefore, travel faster and reach their destination sooner than those sailing away from them. Slower 'rivers' of the oceans are called drifts. Some of these ocean currents were familiar to seafaring men in the days of sailing ships, and the Spanish sailors learned to take advantage of them by directing their course to ride with the currents.

The water in these ocean currents does not mingle with the surrounding water because its temperature and salt content are different. The ocean currents move in four different ways. They may be on the surface, under the surface, from the depth upward, or downward like a slow-moving waterfall.

The warm north and south equatorial currents are the primary ocean currents. They flow from east to west in two streams, one north of the equator and the other south of it in each of the great oceans. These currents are set in motion by the steady trade winds which are directed by the Earth's rotation. When they reach the continents these currents turn aside. The warm waters of the north equatorial current swing north towards the high latitudes in a huge clockwise circle along the east coasts of the continents in the northern hemisphere. The southern equatorial current is turned south along the east coasts in the southern hemisphere Both produce warm currents. These considerably affect the climate of the lands nearby.

The rotation of the Earth causes these currents to turn gradually towards the right in the northern hemisphere and to the left in the southern hemisphere. Currents later return towards the equator along the west coasts of the continents in the form of huge circles carrying cold water with them. *What causes ocean currents?* Several forces are responsible for causing ocean currents. The most important force is probably the wind. The trade winds blow on both sides of the equator and these push the water towards the west. On the other hand the westerly winds blow in the opposite direction and push the waters back towards the east. The great continents that stand on the way of these currents split and divert them both north and south.

The varying density of sea water is another factor that causes the ocean currents. The density varies with the temperature of the water. Cold water is heavier than warm water because water expands when heated. So, a constant current is maintained when the heavy and cold water of the polar regions flows along the bottom of the oceans towards the tropics. It pushes against the light and warm water of the equator and forces it to rise up. Later this light, warm water spreads over the ocean surface and flows towards the polar

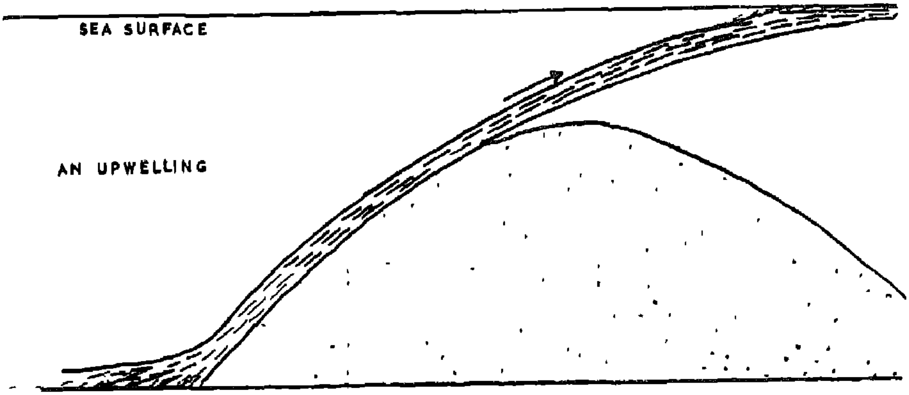

FIG 10. An upwelling. Sometimes underwater mountains force deep water to swerve upward. This upward movement of water is called upwelling. During the upward flow the deep water rises to the surface, bringing with it excellent fertilizers.

areas. There it becomes cold and heavy and so sinks. The process is repeated and a constant circulation is caused. Sometimes underwater mountains also force deep water to swerve upward. The upward movement of water is called upwelling and the downward flow is called the downflow. It is not possible to see these movements but we can detect them with special instruments. Many important things happen when these movements take place in the ocean. During the upward flow the water from the deep sea rises to the surface. This deep water contains a large quantity of dissolved salts which make an excellent fertilizer. Thus this fertilizer is brought to the surface of the sea where it can be used by the small plants that live a floating life. These plants provide the food for other animals that live in the sea. When the downflow takes place large quantities of oxygen are carried down to the deep areas where oxygen is very scarce. But for this purifying downflow deeper areas of the seas would become stagnant. Such areas exist in the ocean when there are no up and down water movements. Good examples are certain deep fjords of Norway and some areas in the Black Sea.

A very remarkable downflow occurs in the Straits of Gibralter. This narrow region connects the warm waters of the Mediterranean Sea which is much more saltier than the Atlantic Ocean. At the Straits of Gibralter the heavier Mediterranean water flows into the Atlantic Ocean close to the bottom. So, the water level of the Mediterranean Sea is lowered and the less salty water from the Atlantic Ocean flows into the Mediterranean Sea to replace it. Since it is less salty than the Mediterranean water it floats over the outgoing water. So here in the Straits of Gibralter there are two currents moving in opposite directions, one outrushing bottom current and another inrushing current above it. These currents were exploited during wartime by the German submarines for their silent movements through this area where the British were on guard.

Still another factor responsible for the cause of currents in the ocean is its salt content. Salt water is much heavier than fresh water. The amount of dissolved salt is different in different parts of the ocean. We have already noticed that the heavy salt water would sink and displace the less salty light water. This can cause a current.

A careful analysis would show that the ultimate force that causes the currents is the Sun. Without Sun's heat there would be very little movement of either air or water. Winds are caused when Sun's heat expands the air. Similarly, the heated water is pushed up by the heavier cold water.

Gulf Stream

The Gulf Stream flowing northwards along the east coast of North America is one of the well-known ocean currents. This current flows like a very huge river about 80 km wide and 1·6 km deep. It is nearly a thousand times larger in volume than the largest river in the world. The Gulf Stream water appears to have a deep indigo blue colour different from the green ocean water through which it flows. It is also warm, being about 80° F. This beautiful and majestic current flows through the ocean and ripples can be seen along its edges. As this warm river passes through cool regions its warm waters may steam as its surface area is chilled by the cold air above it. This causes severe fog in these areas. The Gulf Stream begins somewhere between Cuba and Yucatan. From this region the trade winds push the waters of this current towards the west. The current gradually turns to the north and flows into the Gulf of Mexico. Later, it rushes out of the gulf through the 144 km gap between Florida and Cuba into the Atlantic Ocean. From here it creeps along the east coast of North America like a snake released from its basket. It has been estimated that more than 101,600 million tonnes of water flow past Florida every minute. This current then flows along the eastern coast of the United States and gently turns around the Carolinas eastward as a result of the influence of the rotation of the Earth and by the prevailing winds. The Gulf Stream at about this region comes in contact with the waters of another cold ocean current flowing from the north known as the Labrador Current. This meeting of the hot and cold currents creates one of the most dense fogbanks in the world. The waters of these two currents do not mix with each other but each current travels its own route. The Gulf Stream flows towards England, Norway and the Arctic Ocean across the Atlantic Ocean. The westerly winds pick up the warmth from this warm current and blow over the countries in Northern Europe making the climate considerably warm. The course of the Gulf Stream is definite and a bottle with a message in it thrown into the current from the coasts of the United States would reach Europe in course of time. It was Benjamin Franklin, the American Scientist-statesman who first prepared a chart of the Gulf Stream late in the eighteenth century.

Japan current or Kuroshio

The Japan current known as Kuroshio is Asia's counterpart of the Gulf Stream. This is a famous warm current of the Pacific flowing along the eastern coast of Japan. Just like the Gulf Stream this current also flows northward and turns eastward influenced by the same forces affecting the Gulf Stream. Later, it reaches the coast of British Columbia, the States of Washington and Oregon making the climate of these otherwise cold regions warm and pleasant. The current later turns and flows southward along the coast of California and eventually crosses the Pacific to start the cycle again.

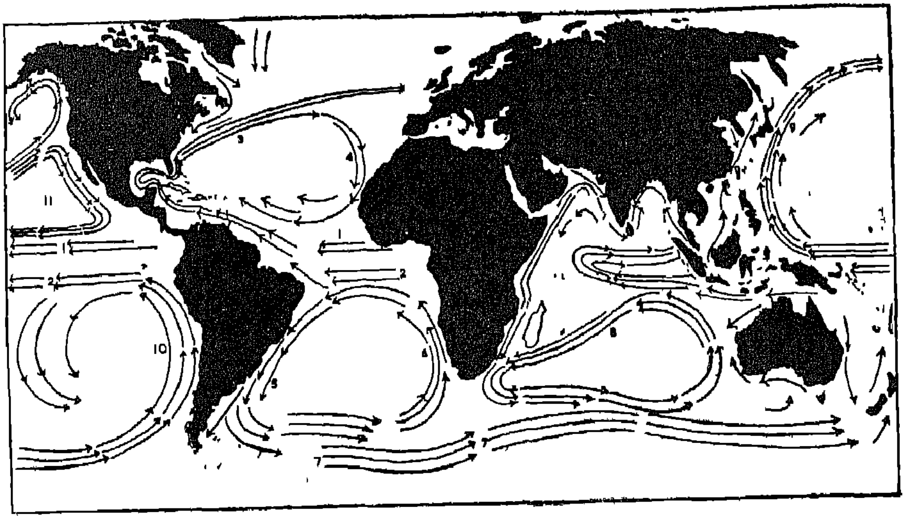

Fig. 11. The ocean currents. 1 & 2–North and south equatorial currents; 3–Gulf Stream, 4–Canaries current, 5–Brazil current, 6–Benguela current; 7–West wind drift; 8–Equatorial current, 9–Japan current; 10–Humboldt current.

This southward flow is caused since the current cannot flow northwards as it becomes caught in the Gulf of Alaska. The name Kuroshio means black current on account of the deep blue colour of its waters.

Benguela current

Now let us study an ocean current which has a very bad effect on the west coast of South Africa. In this region cold winds blow from the south west and an ocean current is developed which flows along the west coast of South Africa. This current is called the Benguela Current. Since the water that forms this current is from the Antarctic Ocean, the current is cold. So, here a cold wind drives the cold Antarctic water along the south west Africa. Cold air is incapable of holding any moisture, but hot air can absorb it and keep a great amount of water in a state of suspension. When this cold wind blows over the African coast it gets heated up and becomes hungry for moisture. Now it absorbs all the available moisture from the neighbouring lands and leaves that part of Africa a barren desert country.

If you look at the map showing the ocean currents you will notice that currents form huge whirls. The great ocean masses are virtually moving in vast whirls. We can see at least five such whirlpools one each in the North Atlantic, South Atlantic, North Pacific, South Pacific and Indian Ocean.

The method of studying the direction of surface currents is to toss sealed bottles into the sea. Inside each of these drift bottles is placed a card requesting anyone who finds the bottle to give information as to where and when the bottle was picked up. These bottles give very valuable information about the speed of ocean currents and also the direction. Much valuable information can thus be obtained from these drift bottles, as valuable as that obtained from very complicated and sensitive instruments. The speed of the ocean currents can also be measured by special instruments called current meters.

The speed of the surface currents decreases with increasing depth and at some depth, there will be no movement at all. Below this level, the current may reverse the direction. Ocean currents occur below the surface as well as in deep water. The deep-water currents flow slowly. These currents play an important role in the exchange of water masses. Cold, heavy water sinks to great depths in higher latitudes and then slowly creeps towards the equator at subsurface levels. This sinking surface water carries oxygen along with it to great depths and ventilates the deep water, making life possible at these levels in the ocean. Hence these cold, sinking masses of polar waters are aptly named the 'lungs of the ocean'.

One of the most remarkable of recent discoveries is the existence of ocean currents flowing in the opposite direction beneath the major surface currents. Four such currents have already been discovered and scientists believe that these currents have a great effect on climate and the productivity of sea life.

Whirlpools

Another type of water movement in the sea is the whirlpool. You might have seen whirlpools in the fast moving waters of a river. These are caused by swift currents which make a circular movement in water. You can create a whirlpool in a bowl of water by stirring it rapidly. By this the water spins round and round and is forced to the sides of the bowl and a hollow will be formed in the centre. This is just like a whirlpool. In the ocean also the whirlpools start from swift currents. These are seen usually around rocks and are dangerous for ships. Small vessels may be sucked down into the swirling centre of these whirlpools. Big vessels may get out of control if caught by a whirlpool and may get dashed against neighbouring rocks. One of the most famous whirlpools in the world is near Norway known as the 'Maelstrom'. This spins round at a speed of nearly 23 km an hour. Another famous one is Charybdis in the Straits of Messina between Sicily and Italy.

Chapter 4

The Winds

DURING THE SUMMER, it is much cooler near the sea coast than in the interior of the country. During the hot summer afternoons we go to the beach to enjoy the soothing and rejuvenating cool breeze. The reason for this is that the ocean functions as a great regulator and stabilizer of temperatures. It is both an excellent absorber and radiator of heat. But for the oceans the world would have experienced unbearable extremes of temperatures. We know that movements

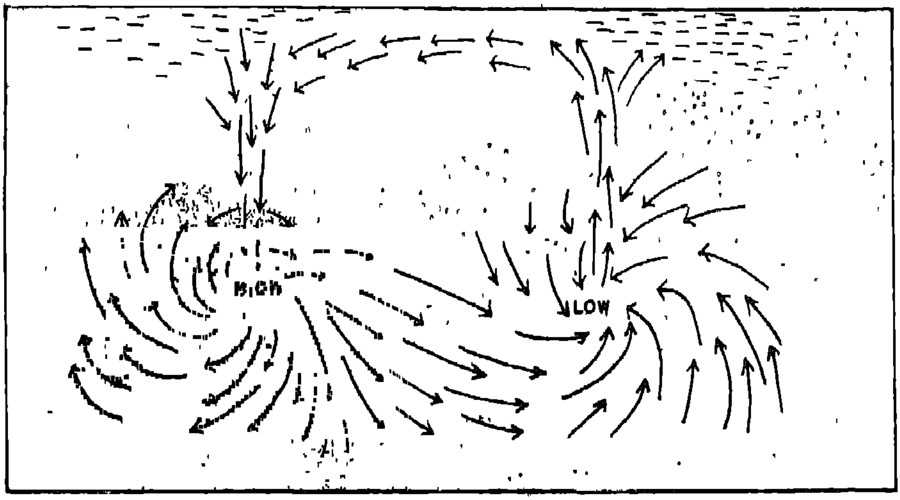

FIG 12. Wind is air in motion, air which is rushing from an area of high pressure towards an area of low pressure.

of the air are called winds. But do you know that winds are caused by the heat of the Sun? The wind blows from a high pressure area to a low pressure area. A low pressure area is formed when the air in that area gets heated, becomes lighter and rises up. In a low pressure area the gas molecules are spaced far apart and in a high pressure area the gas molecules are packed closely together. During the day the land gets heated up much more rapidly than the sea. This is because the sea water takes a much longer time than the land to get warmed up. Further, water needs three thousand times as much heat to warm it than is required to heat air. But the sea can absorb a great amount of heat from the air and hold this heat. So, the air over the land gets quickly warmed during the day. It becomes light, expands and rises up. The pressure over the land, therefore,

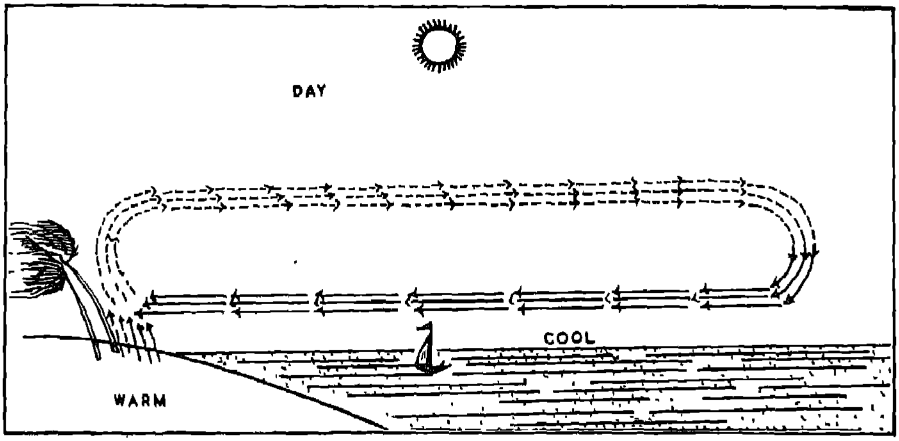

FIG 13 The sea breeze. During the day the land gets heated up much more rapidly than the sea. The air over the land becomes light and rises up So, a low pressure area is created over the land and a cool current of air from the sea rushes in.

becomes less and a cool current of air rushes in from the sea to take the place of the rising air over the land. The result is the sea breeze which is cool, and blows during day time. At night just the opposite happens: the land cools quickly and becomes colder than the sea because the sea water retains the absorbed heat for a much longer time than the land. So, over the sea the air is warm and light and, therefore, it rises up creating a low pressure area As a result, the wind now blows from the land to the sea. This is the land breeze. Thus we see that wind is air in motion, air which is rushing from an area of high pressure towards an area of low pressure. In a way this is nature's own air conditioning and heating system to provide cool or warm air along the sea coasts. The sea can regulate the climate by causing wet or dry, hot or cold, good or bad weather. The Sun, the sea and the air effectively combine to form a huge weather machine.

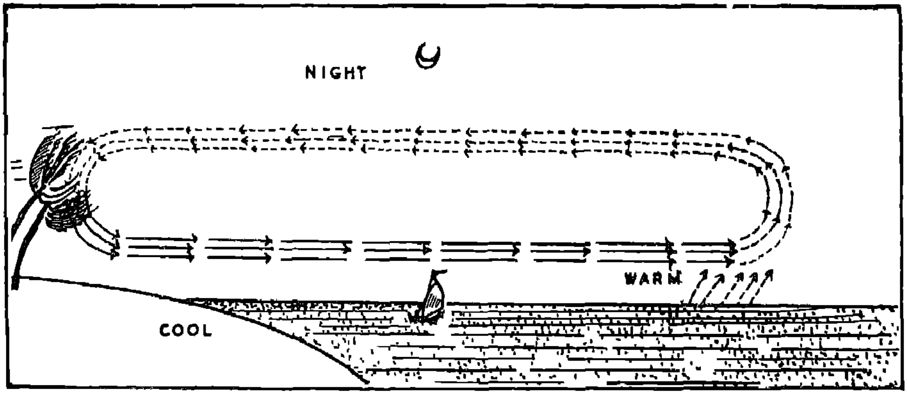

FIG. 14. The land breeze At night the land cools quickly and becomes colder than the sea Over the sea, the air is warm and light and so rises up To take its place wind now blows from the land to the sea.

Good and bad winds

The blanket of air that covers the earth is called the atmosphere. The air is constantly in motion and no area is absolutely at rest. Several forces act upon the air and cause the prevailing winds. These winds blow day and night

By far the most important force that keeps the air in motion is the Sun's heat. These movements of the air are essential for the distribution of moisture which brings the rains. The movement of the air carries the dust and smoke to the clouds and removes poisonous gases and harmful exhalations from our surroundings. Thus it helps to purify the air around us. If air does not move for a long time it will become foul and poisonous. The Sun's heat causes these movements but the direction and the force of winds are influenced by other factors such as the spinning force of the Earth. The ascending and descending movements of the air are caused by the natural law that heated air is lighter and so rises up while cold air is heavy and tries to settle down. Sun's rays are hottest on the narrow belt on either side of the equator. When the air above the equator gets heated up it becomes lighter and rises up. The upper regions are cool and, therefore, this heated air that rises up naturally becomes cool and heavy. So, it tries to settle down to the ground. This is, however, prevented because of the hot layers of air that are constantly rising up from below. The result is that it flows towards the north and south. At about the region of latitude of 30° a part of this air settles down and is pushed towards the equator by the winds blowing towards that direction close to the ground. The rest, however, moves steadily towards the two poles where it sinks downwards and eventually returns to the equator to replace the air that is constantly rising up. Thus if the Earth did not rotate, the heated air rising from the equator would arc towards the two poles and would later come down and return to the equator to replace the uplifted air in the form of two regular circles. Thus a steady circulation of air would be maintained. But this regular cycle is considerably modified and complicated by other forces acting upon it. For example, the rotation of the Earth on its axis at a speed of about 26 km a minute deflects the air currents described above. So, what really happens is that the air does not move straight from the equator to the poles and back, as we should expect, but it moves in a slanting direction. The air currents moving towards the north are slowly shifted towards the east owing to the Earth's rotation. At latitude 30°, a part of the air that settles down flows southwards turning west as it moves. This portion forms the steady trade winds from the north-west. Another part moves northwards and is deflected to the east to form the prevailing westerlies that blow in the north-east direction.

Doldrums

The speed of the winds at the equator is about the same as the speed of the Earth's rotation. Thereforc, there is not much of air movements here. So, on either side of the equator there is a narrow belt of low pressure which is deadly calm without winds. The air here is very humid and hot. This area is called the 'doldrums'. Sailors usually keep off this calm, windless area which they have aptly named the 'way side grave'. Sailing ships have been helplessly stranded in the placid waters of the doldrums under the deathly grip of its windless calm. Sometimes this calm suddenly changes into furious storms, thunder rains and raging seas.

Trade winds

We have already noticed that at about 31° latitude a part of the air that flows towards the polar areas descends to form a high pressure belt in each area. At this region the air turns at an angle of 20 to 30 degrees and rushes towards the equator. The winds which result from this equator-bound air flow are called 'trade winds'. These are very steady winds that blow with great regularity both day and night. In the northern hemisphere they blow from north-east and in the southern hemisphere they blow from south-east to north-west. These are favourable winds that helped sailors in olden days in their trade with distant lands. The name 'trade winds' does not, however, come from their usefulness to commerce but from the regularity with which they blow. 'To blow trade' is an expression which means to blow regularly. These are very steady winds and were no doubt of the greatest help in navigation. The sailing ships under the influence of these faithful winds could make steady progress.

Horse latitudes

On the outer edges of the trade winds are high pressure belts of calm or light winds which at sea are known as the 'horse latitudes'. Weather in this region is generally hot, dry and sunny with little rain. The land areas along this belt have the world's great deserts. This area is named so because in olden days sailing vessels transporting horses from England to Jamaica were often delayed in this hot region on account of the absence of winds. This delay brought about great difficulty, the fodder and water for horses ran very short and the sailors had to throw off the horses into the sea on such occasions. The superstitious mariners would 'see' the images of these horses

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in the white waves at night whenever they passed through this region and, therefore, named this calm belt the horse latitudes.

Westerlies

Beyond the horse latitudes to about 60° north and south is another belt of winds. These are called the 'prevailing westerlies' named so because they blow from the west. The westerlies are caused by the great flow of air from the equator to the poles and they blow steadily at high altitudes At lower altitudes, the condition is different. Cold dry air moving fast down from the north meets the warm moist air moving up from the south. This region of collision is called the 'polar front'. These clashing winds give rise to furious cyclones, tornadoes and hailstorms. All these make the region of the westerlies a very active weather belt on Earth

Easterlies

Beyond the 60° latitude a third belt of the winds can be distinguished. These are called the 'polar easterlies'. This region represents the final phase of the flow of the hot and humid air which started at the equator. By the time it reaches the polar areas it becomes cool, heavy and dry and it settles down and spreads towards the equator to start the cycle again.

Thus we see that many types of winds blow over the wide expanse of the oceans. Some winds are very helpful for navigation while others bring disaster to man. Some regions of the oceans have strong winds blowing over it but others are comparatively calm. The warm, sunny Sargasso Sea is relatively a very calm region, an area practically forgotten by the winds. It lies in the middle of the Atlantic Ocean. The Gulf Stream flows around it and there is not much wind blowing over the area. This causes enormous patches of floating weeds to gather here giving it its name. On the other hand near the south polar regions there are violent winds which sweep across the oceans with terrific force. During the days of sailing ships such areas were dreaded by seamen. Look at the map showing the winds and you will see the 'roaring forties'. These winds are called so because they blow with great force and roar through near latitude 40°. Mariners in ancient times used to avoid this area of rough winds.

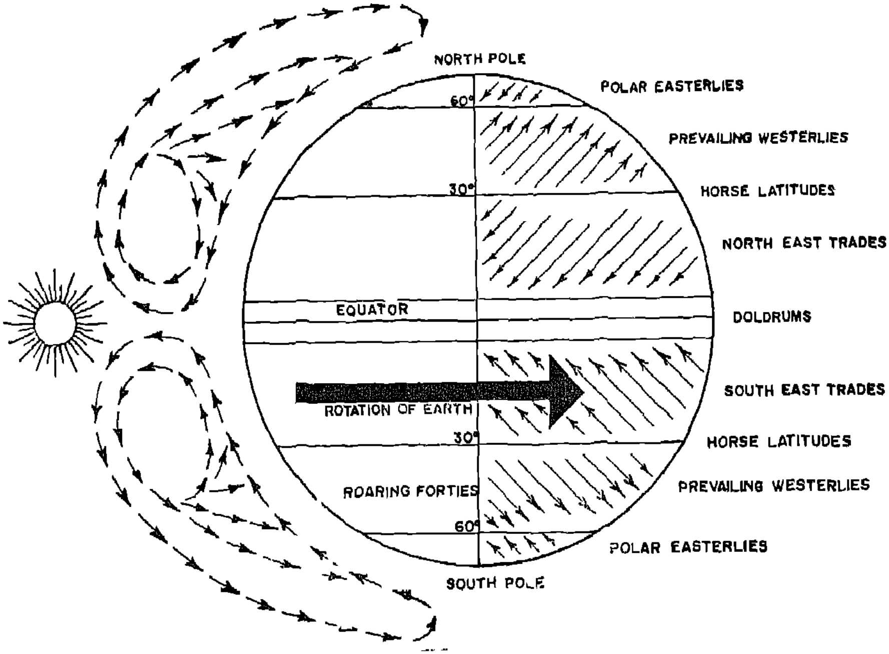


FIG 15 The winds

Monsoons

Seasonal winds known as monsoons occur in Asia. These blow in a particular direction during specific seasons. The monsoons are caused as a result of the great difference in temperature between the land and the ocean. In India there are two distinct monsoons, the south-west monsoon active during summer and the north-east monsoon of winter. During summer the Sun heats the air masses over the Asian continent. By the end of May, a warm low pressure area is formed over north-west India and the adjoining areas of Pakistan, Afghanistan, Persia and Central Asia. This low pressure system takes control of the air currents over Asia, causing a current to flow from the high pressure area over the Indian Ocean. The south-east trade winds from the south of equator are diverted into the Arabian Sea and the Bay of Bengal. These move over the ocean towards the land, collecting large amounts of moisture on their path. These raw winds soon appear over the west coast of India and Burma as the south-west monsoon. While passing over the coastal mountain ranges these cool down and cause the copious annual summer rains. The south-west monsoon 'bursts' over the west coast some time in late May or in early June. Then the winds move eastwards across

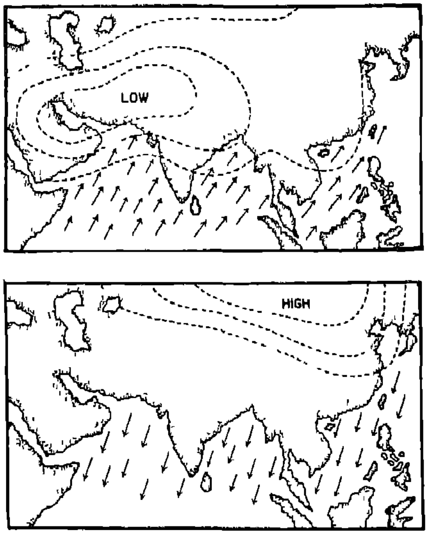


Fig 16 The direction of winds during south-west and north-east monsoons.

Deccan and Central India. By the middle of September these winds withdraw from the country.

In winter (October–January) the process is reversed and winds blow in the opposite direction to become the north-easterly air currents. These winds bring rains over the southern areas of peninsular India specially over Tamil Nad.

The regular action of the monsoon winds was discovered by Hippalus in 45 A.D. and this brought about revolutionary changes in the navigation over the Indian Ocean. For hundreds of years, till the invention of the steamships these winds determined the trade route which the ships followed both in the Arabian Sea and in the Bay of Bengal.

The wealth, prosperity and well-being of the people of this sub-continent is inseparably linked with the arrival and action of the monsoon. It provides the moisture for the food crops and thus maintains life here. But for these winds these areas would have been barren deserts. Even the untimely arrival of the monsoon can bring disaster. Food resources would then fail and famine would sweep over the land.

The monsoon season is by far the most spectacular of natural phenomena in this sub-continent. It 'bursts' over the west coast with an exhibition of the savage force of nature. Dark clouds, driven by the swift south-west winds madly roll across the grey summer skies. Blinding flashes of lightning followed by violent claps of thunder rend the sky. Squally winds sweep through the landscape. Twisting sheets of rain race down like cascades of pebbles, and fall over the fevered earth. This life-giving water prepares the soil to germinate the thirsty seeds within it.

The monsoon is not an ordinary rain or two. Once it bursts it stays to rain and to rain. It stays on to inundate low lying areas, to swell up the rivers with silt laden waters and to burst their bounds. Under its waters the crops may drown. The winds whip up powerful waves in the sea that gnaw and swallow strips of land to leave an eroded coast. The monsoon is not a mere season of rains. It is a phenomenon, the like of which exits nowhere else. It is indeed strange and amazing, yet so real! When the rains stop it is spring in the plains.

Cyclones, typhoons and hurricanes

By far the most dreaded and devastating of all winds that blow over the oceans is that which occurs during the cyclone. It blows spirally inward towards the centre and the whole system can move at a very fast rate. Its rotation is counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere. These winds are called Willy-Willies in Australia, typhoons in the Pacific and hurricanes in the Atlantic. Of these the typhoons cover a much larger area. All these winds are born on the sides of the equator over the oceans. The Sun's hot rays heat up the humid air above the oceans, which begins to spiral upwards in quivering columns. Now more cool air rushes in from the sides to replace it to be drawn up skyward. Air rushing in towards this low pressure area is shifted off its course by the force of the Earth's rotation. The wind, therefore, moves violently in a spiral path. Gradually this circle of twisting air grows larger. It begins to spin faster and faster in a counter-clockwise direction and may attain a speed of 240 to 320 km per hour. The top layers of this twisting mass of light, moist, air get cooled and rain clouds develop. Cooling condenses the moisture and gives out the latent heat. This adds to the energy of the storm. Low, dense clouds envelope the sky, violent squalls lash through the landscape virtually sweeping off every thing on their path and rains pour down.

A characteristic feature of a cyclone is its 'eye'—which is the quiet centre of the storm. It is a zone of dreadful calm which is the most dangerous part of the system. The eye of a full formed cyclone may be several km across and the full width of the storm area may be 160 to 1,600 km. This madly rotating mass of howling air moves across the ocean like a giant spinning top towards the land. Along a long path of several km these dreadful winds can kill thousands of people and damage property worth crores of rupees. These winds are very dangerous to shipping and structures situated along the sea front. Further, they can whip up mountainous waves possessing fierce energy.

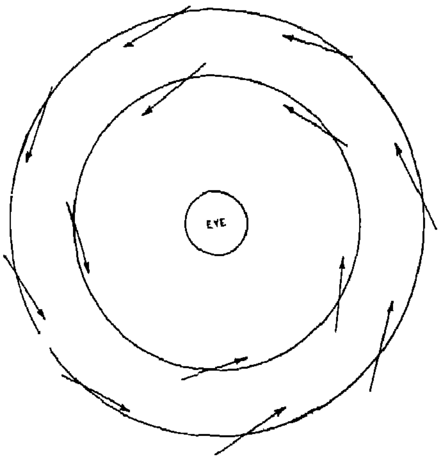


Fig. 17. Air movement during cyclone in northern hemisphere.

The Bay of Bengal is world famous for such revolving storms. Here cyclones occur frequently during the monsoon season and some of them on record are examples of nature's worst rampage. The swirling waters of the tidal wave that hit Midnapur on 7 October, 1737 are reported to have destroyed 20,000 crafts and washed away 300,000 people to their death. In 1832 one town in Kakinada District was left bare by rough seas during a cyclone, killing 20,000 people. Recently mountainous waves swept off the huge Pamban Bridge connecting Rameswaran Island with the main land along with a passing train, killing several persons. Nearly 12,000 lives were lost in East Pakistan as a result of violent squalls accompanying a cyclone in 1965. In 1932, the raging winds, lashing rains and angry seas accompanying a hurricane washed 2,500 people to their death in Cuba. No one can predict just what a cyclone can do. This is perhaps the reason why these peculiar winds are given women's names such as Barbara, Carol and Louise!

The advent of a cyclone can be noted in advance. Some of the useful indications are a drop in barometric pressure, a slow rise in

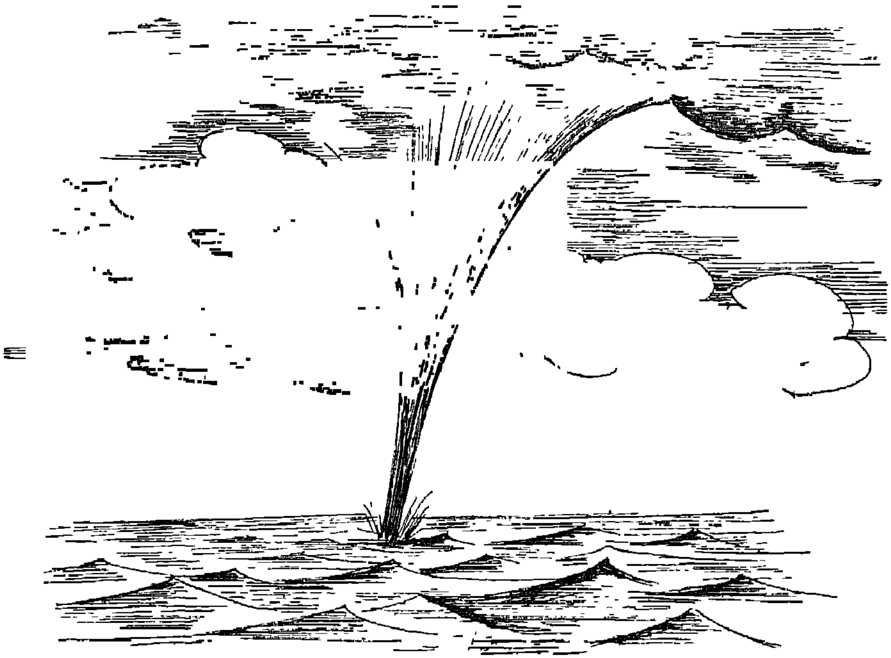
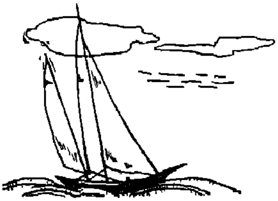


FIG. 18. The water spout

temperature and a succession of vividly red sun sets. A halo round the Sun or the Moon may also be noted and veil-like clouds appear in the sky. A cyclone's life time may range from one day to even a month. Gradually, the warm column of air is replaced by colder streams of air rushing from the sides and the depression gets filled up. These lead to a slowing down of the revolving motion of the winds which eventually die out.

Another curious wind formation on the ocean is the water spout. This is very similar to the tornado that sweeps through the land. This whirling wind picks up water with it and spouts it high in the air. The wind may attain a speed of about 800 km an hour. Captains of ships fear these water spouts and keep clear off them since it is difficult to get out of a water spout once a ship enters it. A method used by seamen to break up a water spout is to shoot at it with guns.

A slight change in the relationship between the sea and the air can bring about drought or flood which can cause great suffering to many people. Similarly, storms, typhoons, cyclones, tornadoes and hurricanes bring great misery and loss. It is hoped that a better understanding of the oceans may help us in more accurate predictions of weather conditions and possibly to control weather.



Chapter 5

The Nature of the Sea Floor

THE FLOORS OF the oceans that lie covered with miles of water are extensive and wonderful. They are not flat as many people think but are more varied than the surface of the land. From the bottom of the oceans project lofty mountain ranges and peculiar flat-topped volcanic mountains some of which are still active. In certain regions there are wide valleys and near the mouths of rivers the floor is split up by deep slashes and canyons while in a few places

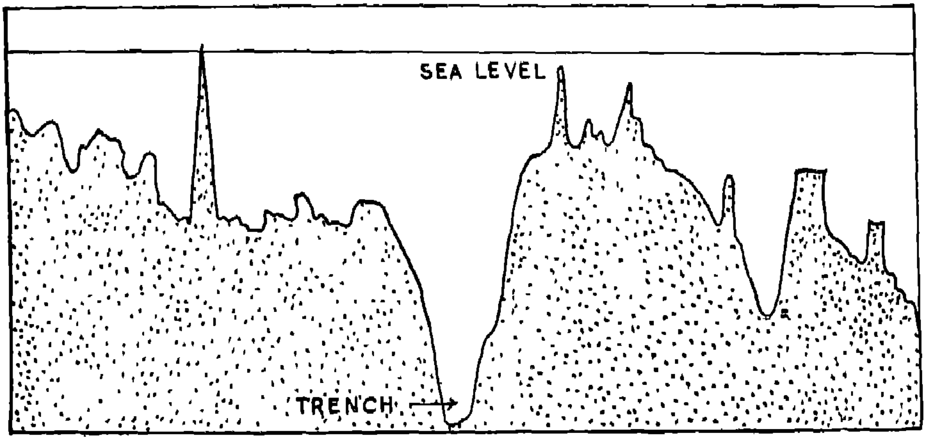


FIG. 19. The nature of the sea floor. From the bottom of the oceans project lofty mountain ranges, peculiar flat-topped volcanic mountains some of which are still active. In certain regions there are wide valleys and deep trenches

there are deep trenches. There are also dark caves, vast barren deserts of sand and under-water coral gardens of great beauty.

This wide ocean floor can be divided into three areas, namely the continental shelf, the continental slope and the abyss or deep sea. The continental shelf is the seaward extension of the continents and it slopes gently and gradually from shore lines. This is very similar to the slope of an inverted dining plate. There is a band of shallow water area which may be narrow or wide. However, in certain regions there is no slope at all, the land steeply falling into the great depths below. In other regions the shelf may be as wide as 320 km or more. Along the Arctic coast of Russia this slope extends for 1,200 km out from the shore line. Along the Pacific coast of the United States it is about 32 km wide. In India it is mostly about 32 to 80 nautical km in width. The outermost edge of the continental shelf plunges steeply downward to the deep ocean floor called the abyss. This is the continental slope. So, this region begins where the continental shelf ends. This slope may be gentle

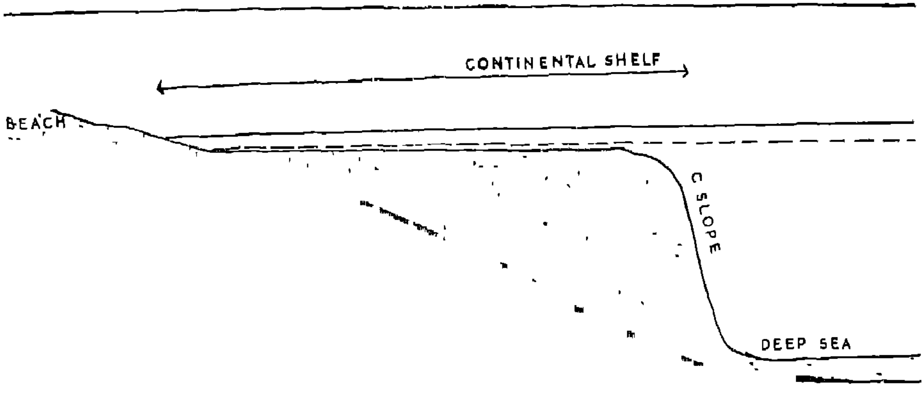


FIG. 20 The major divisions of the ocean floor.

like slanting mountain sides or it may be a sheer dizzy, drop downward of 3, 4 or sometimes 8 km to the deep sea like a wall. One of the steepest continental slopes in the world has been discovered recently in the Indian Ocean, on the east coast of Ceylon. Here the continental shelf falls at an angle of 45° into the Bay of Bengal. There may be great clefts in these slopes called canyons. The third region is the abyss. It stretches from the foot of the continental slopes and is the true bottom of the ocean. Depths greater than 1,000 fathoms (1 fathom=1 8 m) are known as abyssal regions. It is a vast undulating plain dotted with dead or active volcanoes. The Arabian Basin is a deep bowl beyond the mouth of the Indus River. Off Somalia and Kenya also there are deep abyssal plains. The Ganga Basin, the Andaman Sea Basin and the Burmese Oil Basin are the deep sea plains in the Bay of Bengal.

In certain places the floor rises to huge mountains some of which are higher than Mount Everest. All oceans except the North Pacific are divided in the centre by mountain ranges. One of the famous underwater mountain ranges is in the Atlantic Ocean called the Mid-Atlantic Ridge. It extends from Iceland to the southern tip of Africa for nearly 16,000 km along the floor of the Atlantic. This ridge divides the Atlantic Ocean into a western and eastern part. There are only two gaps near the equator in the ridge connecting the two parts of the ocean. Some of the mountains in this range are as high as 3,048 m. Some peaks project above the surface of the Atlantic Ocean to form islands. The Azores is an example. There are mountain ranges in the Pacific also. The Hawaiian and Aleutian Islands are the tips of volcanic peaks that rise from the floor of the Pacific Ocean and project through the surface. Between India and Africa is an underwater ridge, the Carlsberg Ridge named after the Danish Expedition leader. This ridge is like an inverted Y and is connected with the Mid-Atlantic Ridge on the western side. It joins with another ridge extending to the south to encircle Australia. In the north the stem of this Y-shaped ridge bends to the west and passes into the Gulf of Aden and into the Red Sea.

Another kind of mountains that are found in the Pacific have flat tops. These are called guyots. They look as if their tops have been neatly cut off. It is not clear how they got these curious, flat tops. They are believed to be volcanoes of the distant past.

In some regions there are deep trenches which represent the deepest depressions on our planet having depths of even 11 km. In the Atlantic near Puerto Rico there is one trench nearly 8 km deep. Off the Japanese coast there is another vast trench One of the deepest known in the world is the Mariana Trench near the Mariana Island having a depth of 11 km.

Many trenches have been recently discovered in the Indian Ocean. East of the Chagos Archepelago is the Chagos Trench (5,400 m deep) spotted by Russian scientists. Towards the west of Australia is another trench 5,761 m deep. The Vema Trench descends steeply near the Seychelles and was discovered by American Oceanographers. The deepest part of the Indian Ocean is the Diamantina Deep near south-west Australia, having a depth of 4,400 fathoms or nearly 8 km.

American scientists have recently discovered a vast undersea valley in the Andaman Sea. It extends from the northern tip of Sumatra to the south west of Rangoon. Lying one to three miles under the sea surface this valley is 960 km long, 40 km wide and is surrounded by tall mountain peaks. Its floor is covered with thick layers of ooze. These submarine valleys are known to Oceanographers as the Rift Valleys. Such valleys extend down the middle of the Mid-Atlantic Ridge. The fracturing of the mountain ranges through volcanic action is the cause of the formation of these valleys. First of all volcanic action causes the earth to rise and when the action has subsided the earth settles down to form a Rift Valley between the mountains. There are also deep gashes known as canyons under the sea. These are probably formed as a result of the eroding action by rivers or by under-surface avalanches from continental slopes. Two famous canyons are found at the mouths of the Congo River in Africa and Hudson River in America. Along the east coast of India where rivers flow into the Bay of Bengal, the continental slope is also gashed by canyons. Down the mouth of the Ganges is the large and wide Ganga Canyon with steep slopes, discovered in 1948 by Swedish oceanographers. Three other canyons with V shaped profiles have also been recently discovered by American scientists. These are the Krishna Canyon, the Mahadeva Canyon and the Andhra Canyon.

The ocean floor is subject to frequent changes. It is not stable and static. Frequent earthquakes shake it violently and submarine volcanoes sprut out lava and ashes. Sometimes islands emerge suddenly above the ocean surface and then disappear.

The floors of the continental shelf and slope are covered by the earth and stones carried into the ocean by the great river systems. The deep sea floor is covered by a thick blanket formed by the skeletons of animals and plants called the 'ooze'. After death the small organisms that live in the water column above virtually rain down into the bottom and form thick deposits under the great pressure of the water. It averages about 305 m thick in the

Pacific and about 457 m thick in the Atlantic. In some regions massive lime-stone rocks have thus been formed from this ooze which contains lime from the skeletons of these animals. These sediments in some places may be made up of shells of silica as seen in certain areas of the Pacific Ocean. These dead remains of organisms are joined by the dust blown from the land also.

On the floor of the Bay of Bengal the presence of a number of wide channels has been recently noted. These are believed to be carved out by the huge fluid rivers of mud, silt and solid matter which cascade down with considerable velocities perhaps once or twice in a century. One of such largest channels has been located two miles below the surface having a width of nearly four miles and a depth of 91 m.

The floor of the very deep regions is covered by a fine

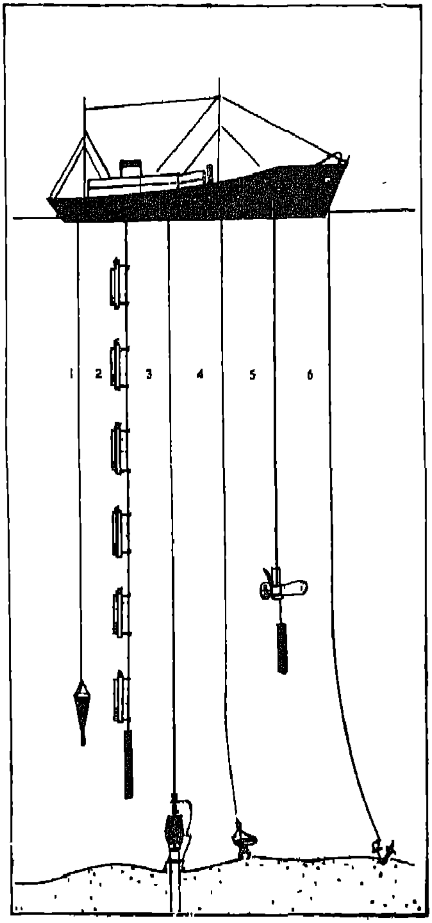


Fig. 21. Some common instruments used in marine research 1-A plankton net, 2-A row of Nansen bottles to take samples of sea water and temperature at different depths; 3-A corer to take vertical samples of the sea floor, 4-A grab to bring up samples of sediments from the sea floor, 5-A current meter, 6- The anchor of the research vessel.

chocolate-coloured stuff called the red clay composed of ooze, volcanic ash and dust from other planets. By a careful study of these sediments from top to bottom it is possible to learn a great deal about ancient life in the sea. The dead remains of animals which lived in the past millions of years are all preserved in these thick layers of ooze of the ocean floor. Below this thick carpet is hard rock. This rock is the Earth's real crust. Scientists believe that a great deal of information regarding the Earth's history can be unfolded through a detailed study of the sediments of the ocean floor.

Our information about the nature of the sea floor is through the help of certain special instruments. In shallow water a curious equipment called 'grab' is used to collect samples from the sea bed. This grab has two jaws. It is lowered in a gaping condition and when it touches the sea bed the jaws close scooping up a sample of the material from the sea floor. Another instrument to study the nature of the sea floor is called a 'corer'. This is a tube 21 to 24 m long made of steel and loaded with weights. With the help of a piston it is driven with force into the sea bottom. This takes a vertical sample of the sea floor sediments. Scientists can also make maps of the ocean floor without seeing it. They use an instrument called fathometer. It is an instrument for measuring water depth.

It is impossible to say how deep a part of the sea is by looking at the surface. A correct knowledge of the depth of the sea is very helpful and essential for navigation, for successful fishing and to map out the underwater continents. The depth of the sea was measured in olden days with the help of sounding lead. This is just a lead ball tied to a long, strong rope. This was lowered into the sea and the rope let out until the lead ball touched the bottom. Then the length of the rope lowered was measured. This method is of course

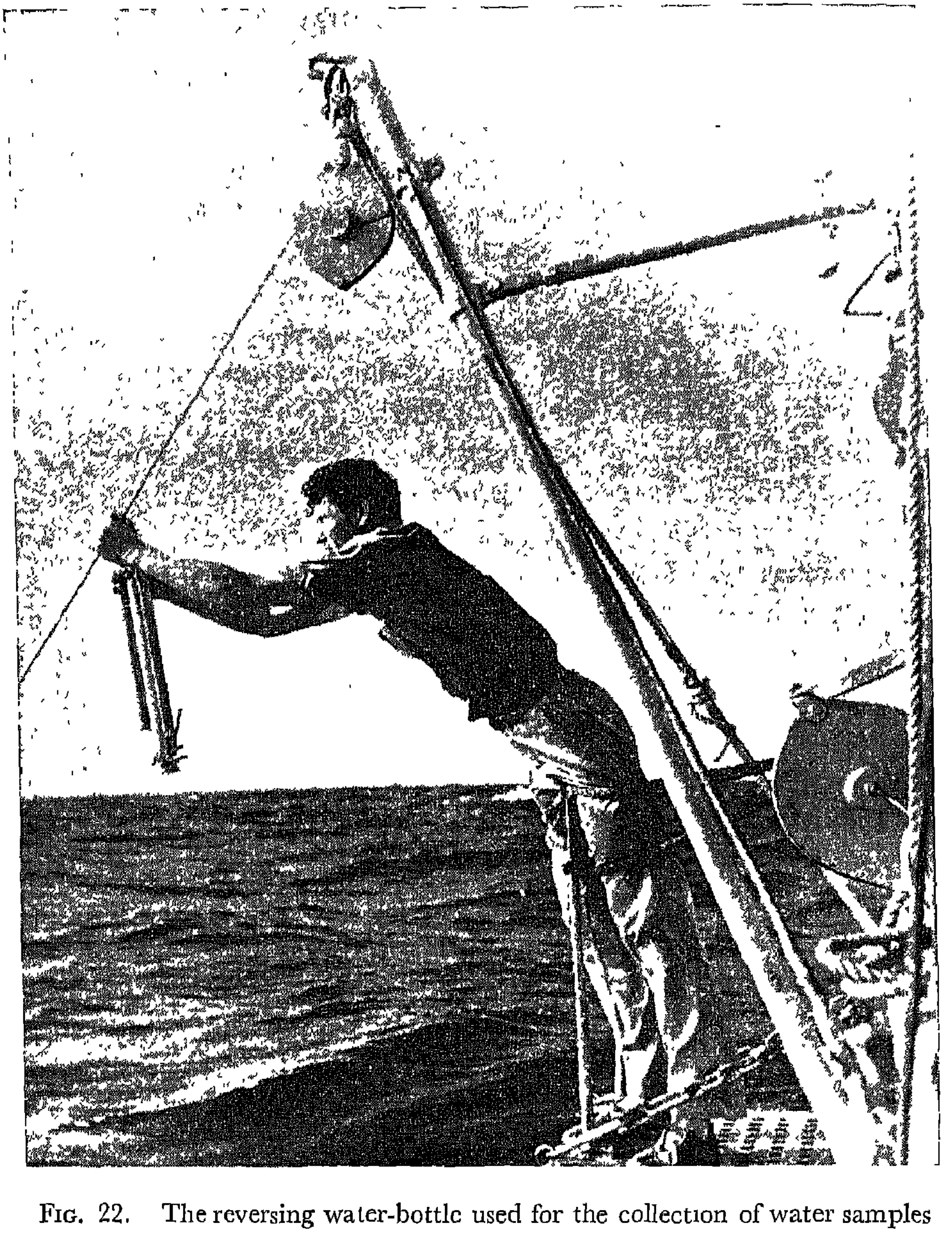


FIG. 22. The reversing water-bottle used for the collection of water samples and recording their temperature from different depths (USIS photo).

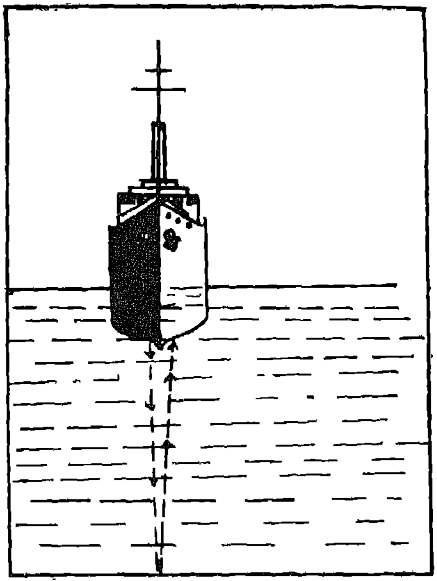


FIG 23. The principle of sonic sounding

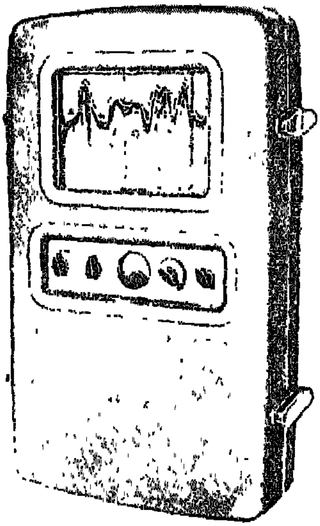


FIG. 24a. An echo sounder (from 'Simrad Echo').

very crude and a time-consuming one when the depth is very great. Now there are new and quick methods, and modern ships are equipped with these automatic devices. Among these is the method called sonic sounding. Here supersonic sound waves are sent down from the ship. Sound travels through water at about 1,524 metres per second. These sound waves will travel down until they reach the bottom. Then they will bounce back to the surface as an echo still travelling at the same rate. So, if we send a sound wave to the bottom of the ocean and measure the time it takes to get back to the surface again we easily know the depth of the water at that point. For example, if a sound travels to the bottom and back in one second we will know it has travelled 1,524 m—762 m down and 762 m back. This will tell us that the bottom of the sea, at that point, is 762 m below the surface. Today this apparatus called the 'echo sounder' is fitted on all modern ships to take soundings continuously during a whole voyage This instrument also automatically makes a record of the varying depths of the water over which the ship passes. There are different kinds of such electronic depth finders. Some indicate the return signal by a light on a dial like the speedometer in a car. The figure to which the light points represents the depth of the water. Other advanced types automatically make a profile map of the sea floor with all details of the sea floor and the location of wrecks and even shoals of fish. These detectives of the deep have rendered fishing comparatively easy since it is possible to locate the position of the shoal of fish with great ease and accuracy.

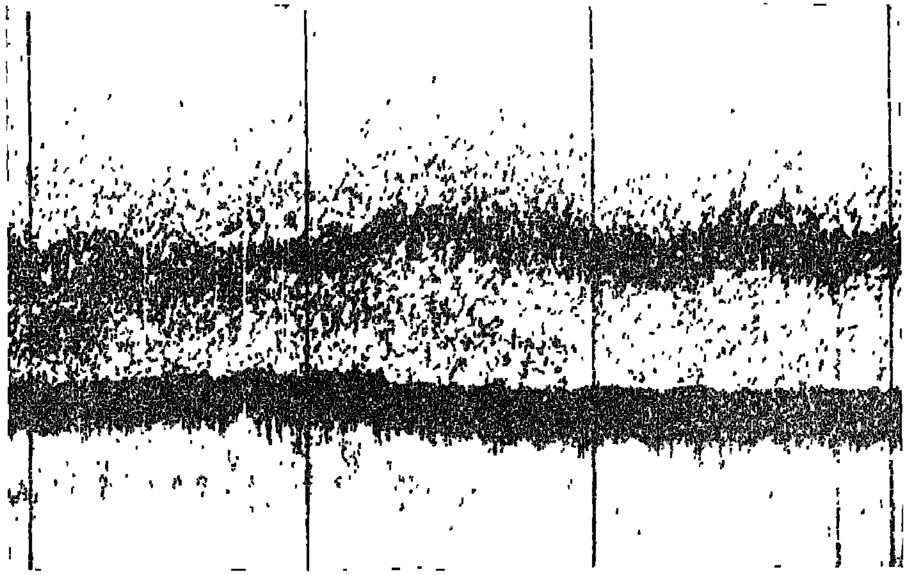
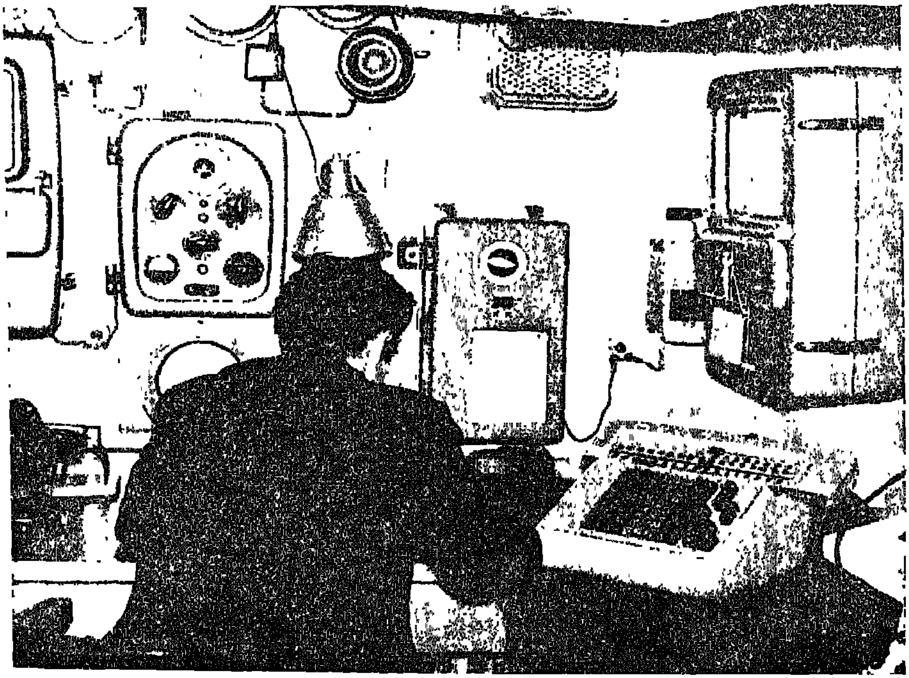


Fig. 24b. Echo diagram of a shoal of fish.

The echo sounder helps the fishermen to spot the fish directly under their boats or ships. Before the discovery of these instruments the fishermen were helpless and felt as 'blind men groping througl an alien country-side'.

A still more promising and recent development is the sonar This is a very complex and accurate instrument. With the hel of this, fishermen can literally 'read' the sea. Whereas the ech sounder can spot objects only directly beneath the vessel, the sona has the additional advantage in that it can be used for spotting objec in front and at the sides as well. This instrument was develope during the war for the detection of submarines and is used extensivel at present for fish detection Sonar for fishermen has been compare to giving sight to blind men.

FIG 25 The Sonar A Russian expert studies sonar readings aboard the oceanographic research ship, 'Mikhail Lomonosov' (UNESCO photo)



Chapter 6

Exploring Under Water

MEN HAVE been curious about the wonders of the vast, murky world beneath the waves. Alexander the Great seems to have been the first man to study the under-water world. He went beneath the surface in a crude capsule called Colimpha, from which he looked around and saw some fishes. To go deep down into the depths was difficult. In former times a diver could remain under water only as long as he could hold his breath. This indigenous skin diving for pearl-oysters and chanks is carried on even today. Now man can remain for a longer period than was possible before. Divers can carry air supply in tanks strapped to their backs. They can explore, take photographs, and search for treasures in sunken ships. The absence of air is not the only difference between conditions in our world and the world beneath the sea surface. Air for breathing can be taken in containers. It is also possible to pump air down to him through a tube from a boat.

When a man dives under the sea, he enters an entirely different world. This new world is one to which he does not really belong. It is a world for which he is not suitable or adapted. He cannot even see clearly under water. Things appear to be out of focus. This is due to light refraction which is different in water. Further, his eyes are not adapted for vision in water.

Divers use masks during under-water exploration. This mask corrects the eye sight like eye-glasses. It is necessary because under the water objects appear to be slightly larger and nearer than they actually are.

Usually, diving is done in clear water. But on special occasions and for special purpose divers will have to work in muddy water. In these muddy waters divers use a special instrument called 'object locator', which serves to indicate the presence of some object.

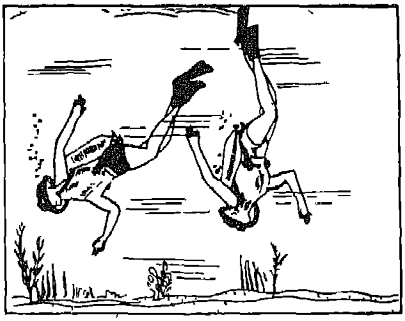


FIG. 26. Two divers

Divers use rubber fins or flippers over their feet for speedy propulsion above and under water. These fins are like the back legs of a frog and make swimming easy and surprisingly rapid without the aid of hands. The hands can, therefore, be used for other purposes.

One of the greatest difficulties the diver experiences is the pressure exerted by water. At sea level the pressure of all the air above is about $10\ 3 \times 10^4$ newton/sq. cm. This is called 'one atmosphere'. But the pressure of water is much more. At a depth of 10m the pressure is increased by another $10 \cdot 3 \times 10^4$ newton/sq. cm. At 20m level the pressure is three times, at 30m it is four times more. That is, the pressure in the ocean increases by one atmosphere for every 10 metres of depth. In deep regions of the sea it may be several million newton per square centimetre. Deep sea fish live under the stress of this enormous pressure. When they are brought up or when they accidentally come up they burst out. A naked man will be pressed into clean pulp at a depth of about 900 m.

The trouble caused by the exposure to pressure is known as 'bends'—a sort of severe pain in the joints especially in the knee or elbow. In this condition it is difficult to straighten the limb concerned—hence the name 'bends'. Bends are believed to be due to bubbles in the fluid which buffer the joints. If a bubble is formed in the nervous system it is more serious. This can cripple or even kill a diver. One of the very important rules in diving is that one must not, after a deep dive, rise up quickly to the surface If he does it may cause sudden death. A man has usually about a litre of nitrogen dissolved in his body. A person who stays for six hours in the air at a pressure of two atmospheres will have two litres of nitrogen When a man is under pressure nitrogen is not exhaled but remains in the body This is not serious so long as he is under pressure, but when he makes a rapid ascent to the surface the nitrogen dissolved in the blood fizzes up like the bubbling of the gas in a soda bottle when its cap is lifted. The reason is that a liquid in which gas is dissolved at a high pressure will form bubbles as a result of the release of the gases when the pressure is lowered. This can kill him or cripple him. Within a few seconds his face turns black and he becomes unconscious. A post-mortem examination will show the blood vessels full of froth. The nitrogen must be allowed to leave the body gradually. This can be done by a slow ascent to the surface giving time for the nitrogen to leave the body. The descent may be rapid and completed in minutes but the ascent must be slow taking much more time to avoid 'bends'. For example, if a diver has spent half an hour to one hour at 52 m, he comes up to 21 m in three minutes, stops three minutes at 21 m, three at 18 m, seven at 15 m, ten at 12 m, 20 at 9 m, 30 at 6 m, and 35 at 3 m. So the total time spent in ascent is 111 minutes—nearly three times as long as he spent at the bottom. There are safe devices at present to speed up the process of decompression.

Divers are subjected to another kind of nitrogen poisoning called the 'rapture of the deep'. This is caused as a result of the bubbling up of dissolved gases like nitrogen in the blood. Nitrogen dissolves in the blood and the amount dissolved is proportional to the pressure. For example, at ten atmospheres pressure after a sufficiently long stay there will be about ten times as much nitrogen in solution as normally. Under these conditions the diver feels very abnormal He looses control over his thoughts. The victim in this case becomes light-headed and irresponsible like an intoxicated person and may commit fatal mistakes. But these symptoms disappear as soon as he comes up to the surface.

The time that can be spent by a diver under water is also limited The deeper the diver penetrates the shorter is the time he is permitted to remain under water. Human body is buoyant So, divers use weights so that they can go down. Weighted belts and shoes are used for this purpose. Such a belt may weigh nearly 32 kg and each boot weighs about 8 kg.

Many people tried to make an under-water capsule that would permit them to stay below the surface long enough to study the animals, plants and other objects. But for a long time no satisfactory solution was available. Pearl divers at Tuticorin and sponge fishermen elsewhere could dive fairly deep depending purely upon the air they were able to hold in their lungs for breathing. The time they could remain thus under water was very brief, only a few minutes. So, the real secrets of the submarine world lay undiscovered for very many years.

Later, diving suits were discovered. The early ones were very clumsy and difficult to use. Only well-trained people could use them. The diving suits were heavily armoured and, so, movements were extremely difficult. With a sufficient supply of oxygen a man in a complete diving suit can descend to a depth of about 152 m. In 1943 two Frenchmen, Cousteau and Gagnan, made an important contribution to solve the problem. They devised an equipment called the 'Aqua lung'. It consists of air-filled metal bottles which are attached to the diver's back. Two tubes connected the bottles to the diver's mouth and there was a valve in between to regulate the flow of air. With this Aqua lung it is possible to dive and descend down to nearly 91 m below the surface. One can swim around and remain under water until the air in the bottle is completely used up. The diver also uses a face mask over his eyes and nose and a pair of rubber fins on his legs to swim in water like a frog. The diver is called the 'Frog man'. Wearing this Aqua lung many scientists dived under water and brought to light many secrets unknown to the world. Beautiful coral reefs, many kinds of sea weeds and several kinds of fishes were observed, photographed, studied and described.

But the aqua lung has its limitations. It is not possible to go very deep into the ocean on account of the very great pressure of the water. Exploration of great depths of the sea can be carried out within a protective metal shell. A round shell is much superior to all other shapes because it can withstand great pressures exerted by the water above.

It was William Beebe and Otis Barton who used such a metal ball to descend into the sea for the first time. This was in 1934 and the metal ball was called the Bathysphere. It weighed two and a half tonnes and its walls were about 4 centimetres thick. Its interior had a diameter of 135 cm and was fitted with quartz windows. Calcium chloride was kept inside to absorb the moisture and soda lime to remove the carbon dioxide. A telephone enabled them to speak to the people waiting at the surface. The whole apparatus was lowered from a ship by a steel cable. They descended to a depth of 923 m in the Atlantic near Bermuda. At this depth the pressure on the Bathysphere was 7,128 tonnes! The experience of these explorers was noteworthy. The light was very dim 213 m below the surface, and it was not possible to read a book. The light around was a strange translucent blue. Still deeper down it turned to be a 'cold whitish-grey'. Still further down there was a blackish-blueness.

A better type of craft was designed later by the Swiss physicist, Auguste Piccard. This is called the bathyscaph, meaning the 'Deep boat'. This is a steel-walled air-conditioned under-water boat. It is not lowered and raised by a line. It can go freely up or down by suitable adjustments. This craft has windows through which the explorers can take photographs under water. With the help of this craft French navy men dived over 4 kilometres into the Mediterranean Sea in the year 1954. One of the famous bathyscaphs is 'Trieste'. This is a specially built craft to withstand enormous pressure. It has a diameter of about 2 m and the walls are 12 to 18 cm thick. There are special apparatuses to supply oxygen and to absorb carbon dioxide. The windows are made of clear plastic 14 cm thick. Using 'Trieste', Don Walsh and Jacques Piccard descended to the floor of the Mariana trench 10,912 m below the surface in January 1960. Nowadays submarines are used for under-water exploration. In 1958 the atomic powered 'Nautilus' cruised beneath the packs of the ice of the Arctic. It stayed

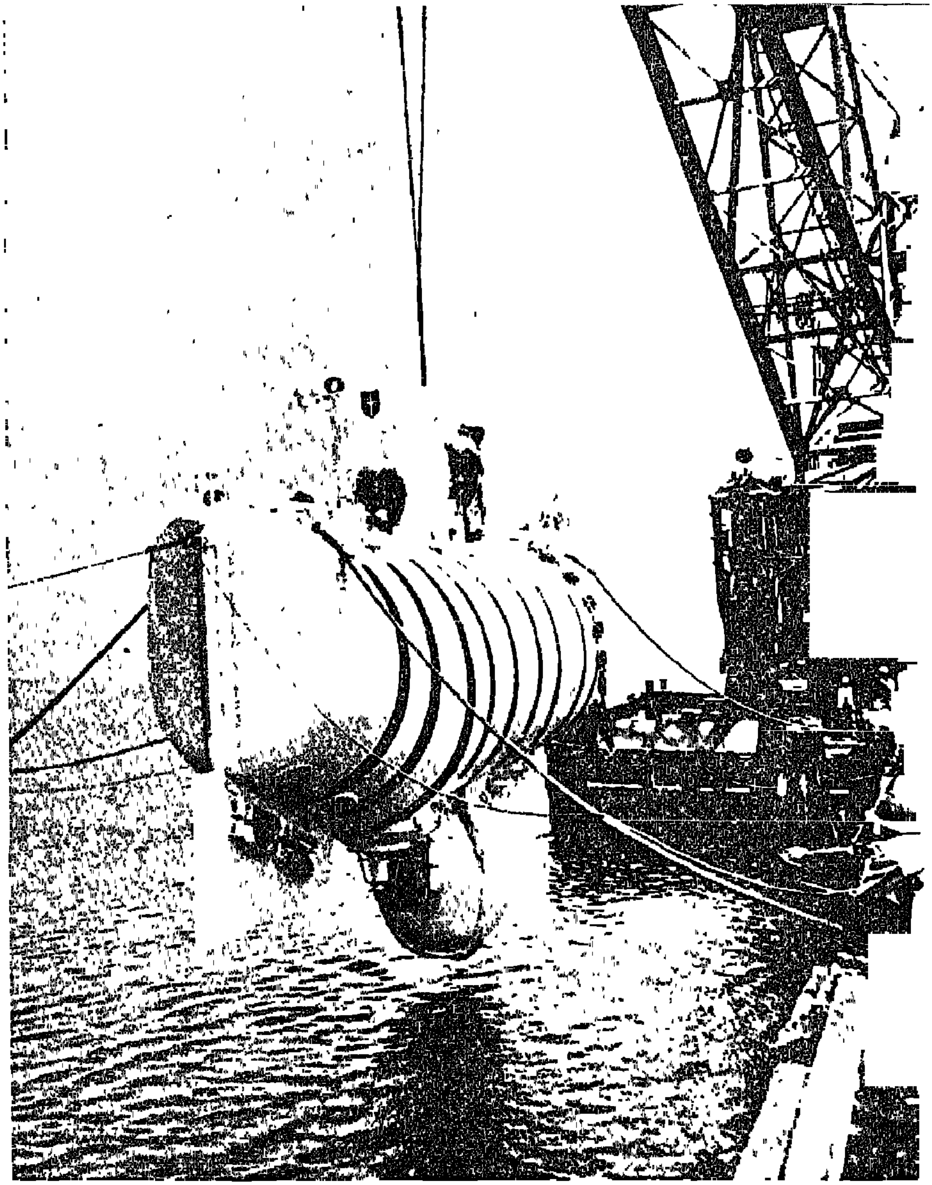


FIG. 27. The bathyscaph 'Trieste' (USIS photo).

below the surface for a period of 5½ days at a depth of more than 122 m. Another submarine 'The Sea Wolf', travelled more than 24,000 nautical km staying below the water surface for 60 days.

It is also possible to take pictures and directly view the curious animals and their surroundings in the very great depths of the ocean where man cannot easily descend Special sensitive flash and television cameras are lowered to the bottom for this purpose. With under-water cameras it is possible to photograph and examine animals and plants both in relation to one another and to their surroundings without disturbing them. Recently under-water television has also been used extensively for observation and study of submarine life. The television camera is enclosed in a suitable water-tight case which can withstand the pressure of water at different depths. Lights are provided for illuminating the under-water scene. The signals generated from the camera are reconstituted into the original picture. The under-water scenes are thus transmitted instantaneously. The advantage of television over camera is that the under-water scene can be viewed continuously from the surface. Further, samples of material from the deep sea can be collected by dredging and trawling, etc.

Now there are devices even for listening to the noises produced by deep sea animals. One device is called the hydrophone. The hydrophone has recorded different kinds of odd noises produced by animals in the sea. These sounds are not very musical but resemble strange mewings, eerie wails, moans, shrieks, cracklings, drummings and the sizzling of hot oil in a pan.

It is an amazing fact that in spite of the fearful darkness, enormous pressure and biting cold of the deep sea many kinds of animals live there such as sea spiders, sea worms, sea lilies and fishes.

Chapter 7

The World Beneath the Waves: Life in the Sea

THE HEAVING expanse of restless water in the oceans looks almost empty without life. But scientists have estimated that there are numerically more living things in the sea than on land. Nearly 140,000 species are known from the sea and about 1,000 new ones are discovered yearly. As has been already stated in an earlier chapter the sea is believed to be the place where the first spark of life appeared and is, therefore, the first home of living things. The vast parade of animals that live beneath the rolling waves include both beauties and beasts, those which are extremely small and invisible to the naked eye and those like the whales which are the biggest animals that live today. The strange animals of the sea also include those that are dull and dreadful to look at, living in the dark dismal depths of the ocean. Near the shore, amidst the forest of sea weeds, dwell countless kinds of queer-looking creatures. The extensive coral gardens of the tropics harbour a variety of animals of great beauty and vivid colouration, while the deep sea contains creatures that are strange and cruel. The study of these curious animals and plants that live within this vast watery world is a fascinating one.

Life in the sea can be conveniently divided into fairly distinct sections; the plankton which consist of minute plants and animals and young stages of larger animals, the nekton or strong swimming creatures such as the squids, fish and whales, and the benthos which include those which live on the bottom walking, creeping, burrowing or fixed to one spot like plants. The plankton are countless minute plants and animals that aimlessly drift about in the currents. Their capacity for movement is very limited. They depend on winds and currents for transport. The plants are unlike those found on the land, being very small, and they float as extensive meadows. These drifting swarms are called the plankton and form by far the greatest bulk of life in the sea. It is not possible for us to see them unless we use a net with fine meshes and strain the water and examine them under a microscope. Billions and billions of these float and can be found almost in all parts of the oceans where light penetrates. During certain seasons the plankton become so thick that they turn large tracts of the ocean surface into a kind of thick, slimy soup. The plant plankton is called the phytoplankton and the animal plankton is called the zooplankton. The larger animals like the jellyfishes, fish larvae, arrow-worms are called macroplankton.

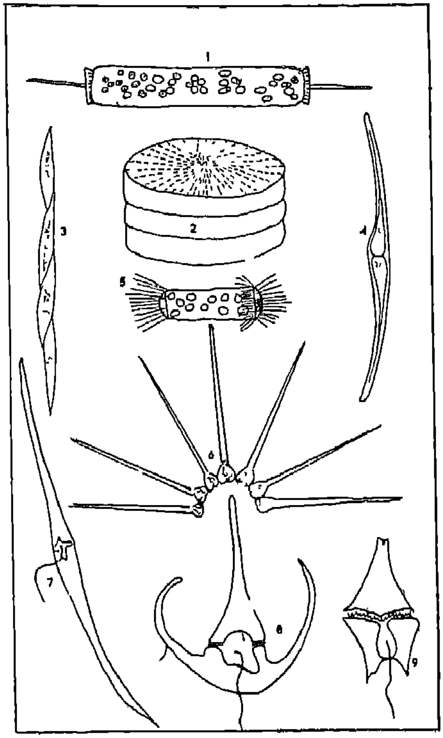


FIG. 28a. The tiny drifting plants of the sea, the diatoms and dinoflagellates.

The smaller ones are called the microplankton and very tiny ones are called nannoplankton and the still smaller ones are called the ultraplankton. The plankton are a whole world of small plants and animals which drift in the seas. The majority of these creatures are either too small or transparent to be easily seen by the eye and hence have escaped the attention of the common man. Yet they occur at times in such abundance that the colour of the oceans may be changed by them to green, yellow, brown or red. There are other animals in the sea which are good swimmers unlike the planktonic organisms. These creatures have good powers of movement and can roam about widely even against the currents in search of food. Such animals are called the nekton, meaning swimmers. There is still a third group of organisms in the sea. They lead a double life. In the early part of their lives they are found in the plankton as drifting forms. Later, forms like the mussels, sea squirts, oysters, barnacles, etc. settle down on rocks or piles or sea weeds to lead a stationary life. Others like clams, conches and starfishes settle down on the sea floor and lead a creeping life. Thus the countless numbers of sea animals can be conveniently classified into three groups, namely the drifting type or plankton, the swimming type or nekton, and the creeping and fixed forms called the benthos.

The plankton

A. The meadows in the sea: We have studied in an earlier chapter that sea water is a solution of nutritive substances. This helps the growth of countless numbers of plants. The plants of the sea are chiefly very small and simple and consist of single cells. They are, therefore, very unlike the mighty trees, beautiful shrubs, lush weeds and green grasses that grow on the land. They have neither the

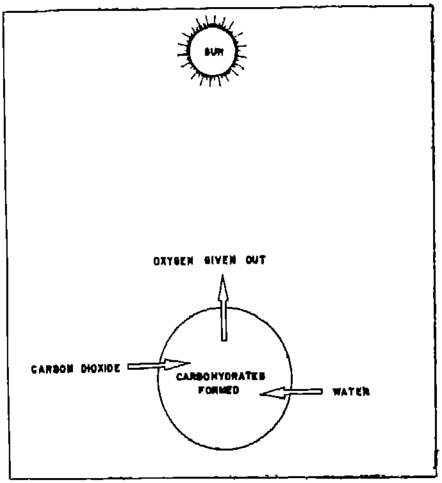


FIG. 28b. The process of photosynthesis.

root system nor the elaborate shoot system with stems, flowers and fruits characteristic of the land plants. Some of these plants are so small that they can be seen only with the help of a microscope. Each one of these tiny plants is a single living cell floating freely and invisibly through the water. These simple, tiny plants directly absorb needed substances and carbon dioxide for preparing their food and oxygen for respiration from the surrounding water. Some of these organisms are on the border line between plants and animals and it is difficult to say which is which. These minute plants have the green colour like the plants around us. This green colour is due to the presence of a wonderful substance called chlorophyll. This substance has the ability to trap the energy from the sunlight and synthesise sugars and starches from simple substances like carbon dioxide and water. So, they function as producers of the food needed by all the other animals that live in the sea. From this it is clear that all the animals in the sea will starve if plants are not there to produce the food. That is why they are called the primary producers. The basis of life in the ocean is this green soup of tiny plants. The countless types of animals that live in the sea depend on them directly or indirectly for food. These plants are the first source of all the food in the sea. They represent the first link in the food chain existing there. Small plant eaters feed on these. The plant eaters are called the herbivores. These herbivores are then eaten by flesh eaters or carnivores. The smaller carnivores are then eaten by larger carnivores and so on. This is the reason why it is said, 'all flesh is grass'. The animals that feed on the vegetation and those that feed on the herbivores, etc. are called consumers. This is because they consume the food originally prepared by the plants. The consumers are found everywhere in the ocean. But the producers are found only on the upper sunlit areas of the sea. This is as it should be since food can be produced by plants only in the presence of sunlight. Sunlight can penetrate to a depth of nearly 100 metres. Below this region it is dim and plants become less and less common as depth increases. Finally plants become totally absent where it is lightless and dark. So animals of the lightless regions of the sea are all flesh eaters or depend on dead plants and animals that rain down from above for their food. Thus life in the sea goes on in a great circle. When an animal or plant dies its body undergoes decay.

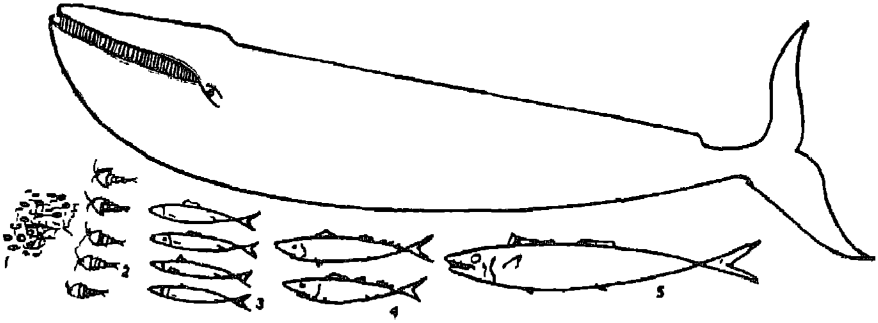


FIG. 29. The food cycle in the sea. The tiny plants (1) are eaten by copepods (2), the sardines (3) eat the copepods, the mackerels (4) eat the sardines, the large tuna (5) eats the mackerels. The basking shark and the blue whale can feed directly upon the tiny animals and plants with the help of special devices in their mouths

This is due to the work of minute creatures called bacteria. These are found in countless numbers everywhere The parts of dead animal or plant are broken up and converted into substances that are soluble in water. These are then used by the plants for their growth. The plants are eaten by animals. The smaller animals are eaten by the larger ones and so on. For example, the tiny plants form the food of the copepods, the sardines eat the copepods, the mackerels eat the sardines, the large tunas eat the mackerels and so on. The basking shark and the blue whale can feed directly upon the plankton with the help of special filtering devices in their mouths. Life in the sea is thus a savage struggle. It is a fierce and cruel life where brute strength is power. The struggle for survival is intense. It is a constantly repeated cycle of cruel slaughter, the larger ones killing and feeding on the smaller ones, each animal representing one link of a food chain. In this fierce contest each tries to keep alive the longest by feeding on others but sooner or later gets caught by a more powerful one and is eaten up. Like a relay race the food chains run in circles and keep constantly returning to the starting point. The interesting fact is that this is a rather curious race that is never won or lost because it never ends. This is the food cycle which is a dreadful drama enacted by a variety of creatures. The scenes depict their birth, brief and precarious life, ultimate death and dissolution or their tragic end as food for a stronger carnivore.

As stated already the green pastures of the sea play a very important role in the life of the sea. Without them no life is possible. The process by which plants manufacture food materials from inorganic substances in the presence of sunlight is called photosynthesis. During this natural process they absorb carbon dioxide and give back oxygen to the sea.

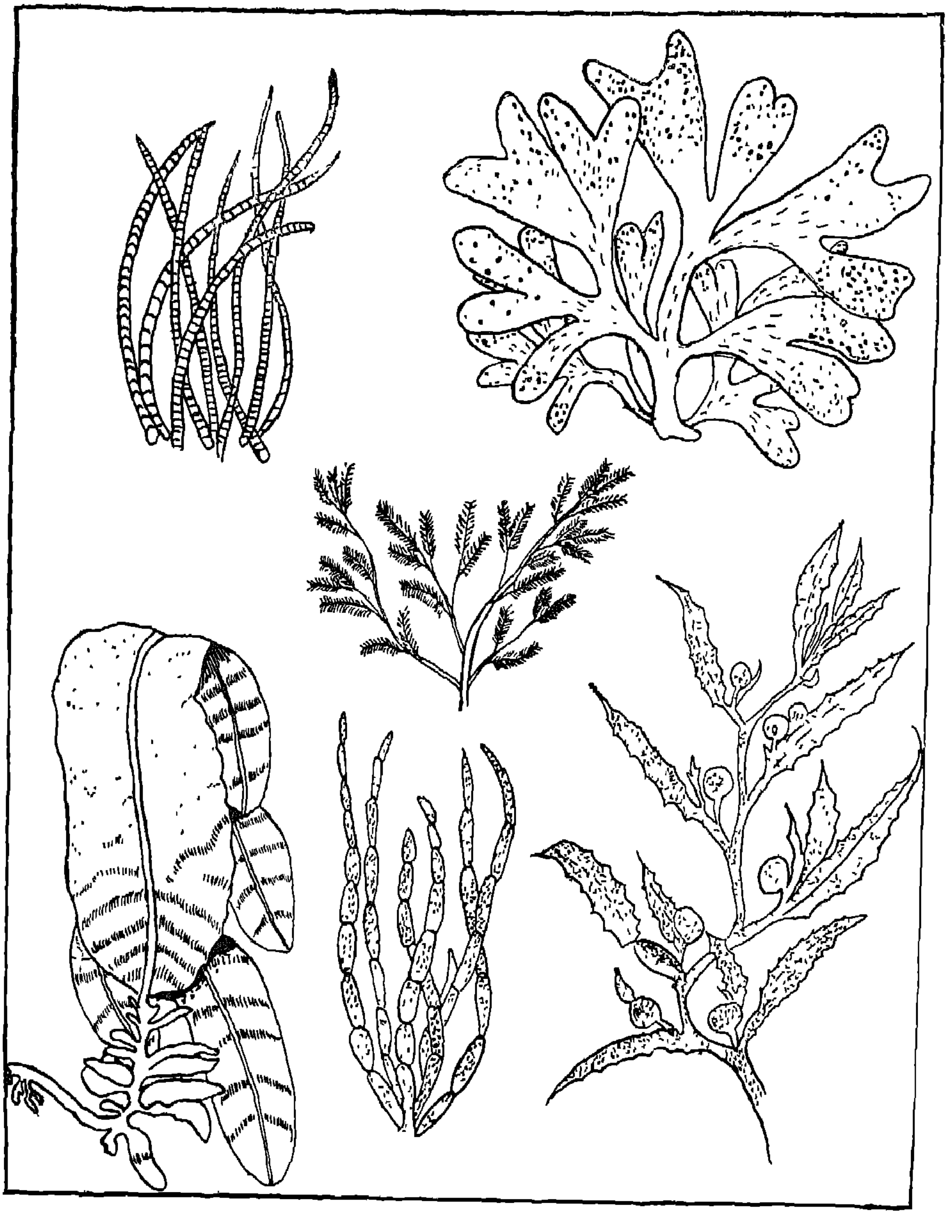


FIG. 30 Some representative plants of the sea

If you study a representative sample of the different types of plants that live in the sea you will be surprised at their sheer, simple nature. None of the plants that we see on the land can live in sea water. None of the sea plants produces any flowers or fruits. Ferns and mosses are not represented in the sea. The green algae found in abundance everywhere in fresh water are not found thriving well in the salty sea water. The most characteristic types of algae of the sea are the brown algae and the red algae. Usually, they are in the form of flat sheets or like long ribbons, or streamers. The weeds, *Sargassum* and *Fucus* are all brown algae and these are usually found near the coast. They grow as single plants or in small patches or as lush growth of a forest. Some cling to the bottom while others float near the surface of the water. The Sargasso Sea in the Atlantic is a floating forest of the weed *Sargassum* These sea weeds are important and useful to man since many kinds of chemicals are extracted from them. But the most important of all the plants in the oceans from the point of view of food production are the tiny, one-celled plants. They are called the diatoms and the dinoflagellates. These are present in countless numbers in the blue-green surface waters. These are really the rich pastures of the oceans and the green colour of the sea is mainly owing to the presence of these plants. These represent a vast floating grazing ground for the animals that feed on them. It is almost as wide as the seas themselves. The diatoms are single, plant cells and can carry out all the functions of the plants. Each diatom lives within an outer shell made up of silica, the substance used in the making of glass. So, its cover is transparent and very hard. This little glass house is porous and often beautifully marked. Diatoms are of several kinds. Some look like wheels, saucers or plates, others resemble ornamental boxes, bracelets or brooches, while a few are like parachutes or rising suns. Sometimes they are oblong, round, triangular and often linked in delicate chains.

The diatoms are built for a floating life and they can multiply very rapidly. Within 24 hours a single cell will divide and continue to do so until there may be several of them. The diatoms and the dinoflagellates supply almost nine-tenths of the plant food of the sea. Oil is the principal result of diatom photosynthesis. The oil content of the whale's body and of the fish and shark liver oils with their valuable vitamins A and D are derived from the oil droplets of diatoms. After death these diatoms constantly rain down and their glass-like silica boxes settle down on the sea floor and form very thick deposits. This forms a characteristic type of ooze which is used for a variety of purposes today such as chemical filter, etc. The dinoflagellates are also single-celled organisms, the majority occurring in the sea. Sometimes, under certain conditions, they occur in enormous numbers and impart a yellow, yellowish-green or reddish colour to the sea water over wide areas. Some of them can produce light, and sea water may glow with their abundance. The fire lake is Bahamas and the 'burning of the sea' reported by mariners are due to these creatures. The phenomenon called 'red tide' which kills millions of fish is caused by a type of dinoflagellate called *Gymnodinium brevis*. But, on the whole, the dinoflagellates, like diatoms, are of great importance to the food production in the sea. Estimates of the food-producing power of the seas show that it is about 300 times that of the land area of the world.

B. The drifting swarms: The zooplankton contains different kinds of small floating animals. Almost every major group of animals can be found in the plankton for at least a brief period. It includes the early stages of animals that live a creeping life or fixed life as adults. It also includes the eggs and larval stages of fishes. Plankton is a virtual nursery for the major groups of animals found in the sea. It also includes forms which lead a floating life throughout their lives. Some of these are tiny, others are just visible, while a few are fairly large forms. The tiniest of them all are the members of the primitive, single-celled animals or Protozoa. These are very common in the sea. The protozoans are the simplest of animals and can be seen only with the help of a microscope The protozoan body is remarkable since it consists of just a single cell unlike ours composed of billions of cells. The marvellous thing about these creatures is that the simple, single-celled body has the ability to perform all the essential functions of an animal with complicated tissues and organs. The simplest types of protozoans look like tiny, shapeless drops of jelly possessing the spark of life. Without any special organs to do specific functions a protozoan can breathe, feed on small particles, move about and multiply its kind. It has no lungs, no mouth, no legs or fins, no reproductive organs and no trace of a brain. It breathes through its body surface and moves about by flowing itself in the direction in which it wants to go. While feeding it flows itself around its prey, forms a tiny temporary bubble-like stomach in which the food is digested and after absorption the unwanted portion is got rid of by the body flowing away from it. While some protozoans are simple and naked, others are protected by shells composed of calcium or silica. These minerals are absorbed by the protozoans from the surrounding water and later secreted to form simple or complex types of shells. The shells of certain forms are of great beauty. Through the minute openings in the shell the body substance can stream out in the form of slender threads for feeding and movement. The protozoan usually reproduces its kind by dividing into two or more pieces, each piece becoming a daughter individual. It is thus an amazing fact that these simple forms of life perform all the essential activities of animals with complex tissues and organs and achieve the same ends in life!

These animalcules are abundant in all the seas of the world. Multiplying with astonishing rapidity some species appear in countless numbers in some areas of the sea during certain seasons. Their life span is small and every day many of them are coming to life, and many of them are for ever dying. The shells of the dead forms virtually rain down and form a thick carpet on the sea floor. These dead shells are called the ooze. The shells composed of calcium pile up layer after layer on the sea floor of some areas to form thick deposits of chalk several hundreds of metres in thickness. In some parts of England (cliffs of Dover) this sea floor of chalk has risen above the water level and the material is used for making chalk. Some protozoans have special organs for moving about. A part of the body is produced into a whip-like tail. By lashing this tail they can move about. Some have small hair-like structures over the body and by moving them in a regular manner like the oars of a boat they are able to move about in water. In the sea some of the protozoans multiply to such enormous numbers during certain times that in some areas they actually give a reddish colour to the sea water. Some protozoans like *Noctiluca* can give off a beautiful cold light like the fireflies. The light produced by millions of these can brighten the sea surface for miles and make the sea water sparkle with little spots of light. A typical drifting protozoan is *Globigerina*. This form at first secretes a chamber of carbonate of lime in which it lives. As it grows this globe-like chamber becomes too small and a larger one is secreted and later a still larger one and so on until a group of chambers of different sizes are produced. Long hair-like spines project from the surface of the shell. The shell has many small openings through which the body substance can be projected as long slender threads. These creatures are found in large numbers in the plankton, when the sea is calm. When they die their shells literally rain down over the sea floor and form thick deposits there. Such deposits are found over thousands of square miles in the Atlantic Ocean. *Globigerina* is found in large numbers in the warmer seas and several kinds are met with in the tropical waters.

Another group of Protozoa found in the plankton is the Radiolaria. Some of these are remarkably beautiful. They have glassy skeletons of exquisite delicacy and beauty. Some look like the decorative pieces found on Christmas trees. The skeletons of these creatures are found as thick and extensive deposits on the floor of the Pacific and Indian Oceans.

A third representative of the Protozoa found in the plankton is called the night light or *Noctiluca*. Sometimes these minute creatures appear in enormous numbers to make the sea water thick like silvery soup. *Noctiluca* gets its name from the fact that it can glow in the dark. It is luminescent. It can emit a cold bluish or greenish light.

Yet others called ciliates have more complex bodies and are covered by fine 'hairs' called cilia. By the beating of these cilia they can move about and collect their food.

Jelly fishes are conspicuous and prominent members of the plankton. These are more advanced creatures than the protozoans. The body of a jelly fish is composed of many cells. These have special organs to do special functions. A jelly fish is shaped like an

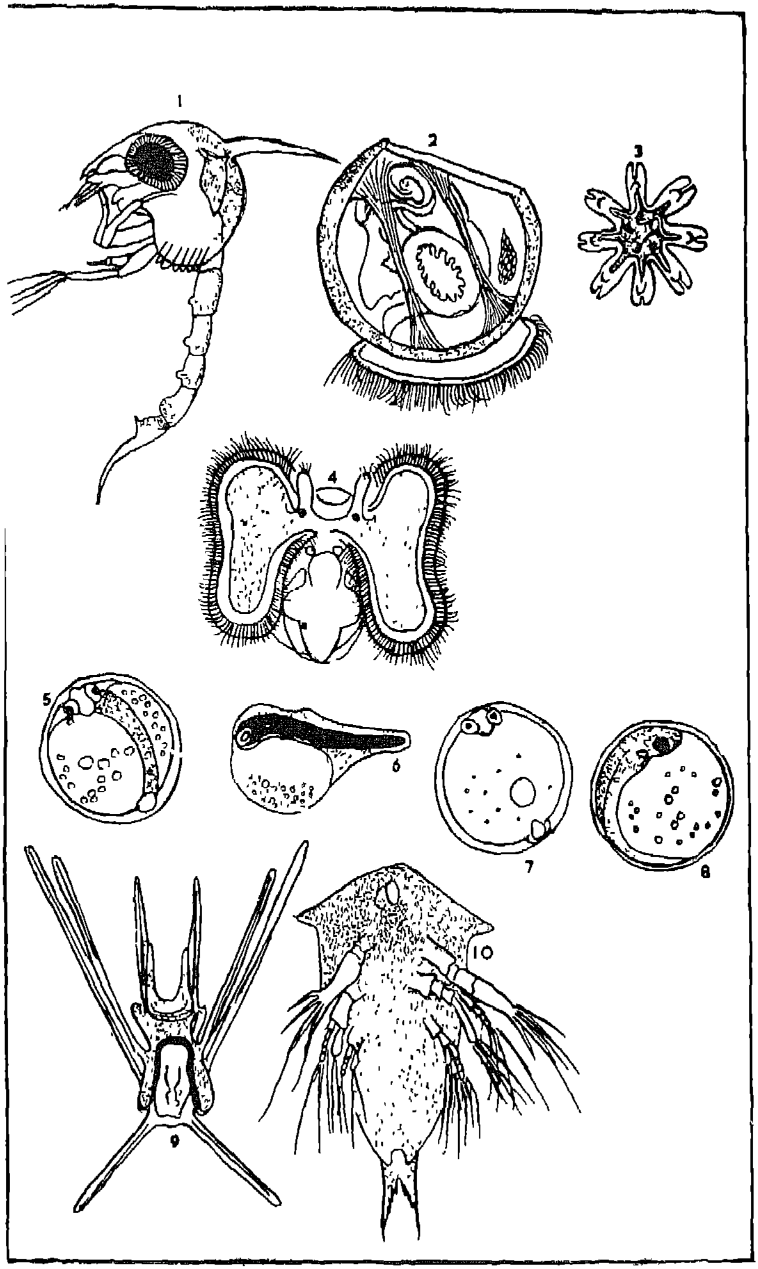


FIG 31. Some larvae of animals found in the plankton 1–Larva of crab, 2–Larva of oyster, 3–Larva of jellyfish; 4–Larva of sea snail; 5 to 8–Developmental stages of fish, 9–Larva of sea urchin, 10–Larva of barnacle

umbrella with crude eyes, special arms for catching food, nerves and muscles. So, it represents a more advanced animal than the protozoan. It moves about with a peculiar movement similar to the opening and closing of umbrellas. The mouth develops a stalk at the place where the handle of the umbrella is placed. These creatures can be seen washed upon all our beaches in large numbers. They are unpleasant creatures in the sense that if you handle them you get irritation and itching on account of their stinging cells.

Another creature which lives a floating life and which is related to the jelly fish is the Portuguese man-of-war or *Physalia.* It is called Portuguese man-of-war because its floating sail looks like that of the sailing battle ship of the Portuguese. Sometimes it is a foot long fitted with a gas float to keep it afloat. *Physalia* is actually not a single animal but a colony of several animals. It has a float which looks like a big bluish, pinkish or purple soap bubble. Hanging beneath this beautiful float are several ribbon-like multi-coloured streamers. The streamers have various duties. Some are stinging tentacles used for defence and for the capture of small fishes and other small sea creatures. These tentacles are armed with millions of stinging cells to poison the prey and make it numb and helpless. Some serve as guards for this creature. Besides the fighting units there are other members. Some are vase-shaped bodies whose work is feeding and nothing else. Others resemble grapes and these produce eggs which would add more members to this floating colony. This curious 'ship' sails with the help of the wind. These are sometimes dangerous to man. The sting of these may become serious and sometimes fatal.

The comb jelly or sea walnut has a pear-shaped jelly-like body. It is an extremely beautiful creature. Its tissues are crystal

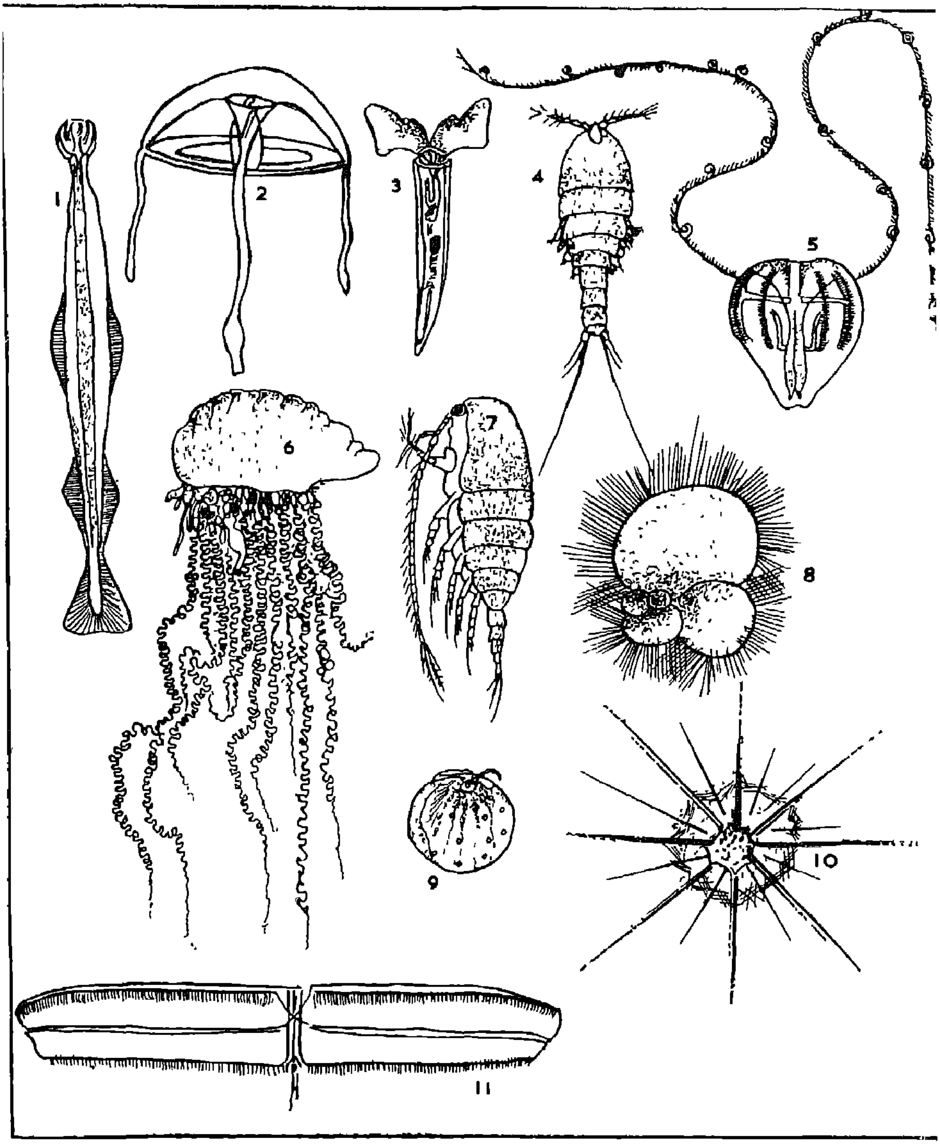


FIG. 32. Some representative animals from the plankton. 1-Arrow worm; 2-Jellyfish, 3-Sea butterfly; 4&7-Copepods; 5-Comb jelly; 6-Portuguese man of war; 8-Globigerina; 9-Noctiluca; 10-Radiolarian; 11-Venus girdle.

clear. As it moves about in water it flashes a lovely bluish light. These planktonic creatures feed on small fish fry and other small animals. They have stinging cells and typically have only a single pair of tentacles. They swim by the movement of fringed comb plates using balancing organs to keep them upright in the water. Some comb jellys are egg-shaped and some are ribbon-like, as the 'venus girdle'.

Sea butterflies are also members of the plankton. They are relatives of the snails and clams. In these animals the foot is modified as flat wing-like structures to help in floating about in the water. In certain parts of the sea these are found in large numbers. Sea butterflies are elegant creatures with almost transparent bodies and paper-like shells.

Another important element of the plankton consists of the arrow worms. They are transparent swift-moving animals shaped like an arrow. Arrow worms are voracious creatures with powerful hook-like teeth around the mouth to catch the prey which consists of copepods and small fish.

Copepods or 'oar feet' are found in all the seas and are important members of the drifting swarms. They belong to a very big group in the animal kingdom called Arthropoda, the members of which have all jointed legs. Their bodies are segmented like those of earthworms or butterflies and have rigid body covers. This cover is periodically shed as the animal grows. Some of their well-known relatives are crabs, shrimps and lobsters. Copepods are small, only a few millimetres long, but are found in large numbers. They are important animals of the plankton since they form the food of other larger animals particularly fish. Copepods feed on small floating plants and in turn serve as the food of fish useful to man. Big catches of fish are usually found near great concentrations of copepods.

Starfishes, sea urchins, brittle stars and sea cucumbers are all creeping animals on the sea floor but their young larval stages are prominent in the coastal plankton. The larval stages of oysters, clams, conches, snails and worms, etc. are found in the plankton. These planktonic young ones are totally different in appearance and habits from their parents. There are distinct advantages for this type of floating life in the early stages of these creeping and fixed animals. As young ones they are transported to far off places from their parents and this helps to avoid overcrowding.

There is an amazing interdependence among the different kinds of animals that live in the sea. It can be clearly seen when we examine some of the food chains that exist in the sea. The tiny drifting creatures of the sea serve as food for small fish and other animals. These in turn are eaten by larger species. Scientists have estimated that about 10,000 kg of diatoms are eaten to make 1,000 kg of copepods, and 1,000 kg of copepods produce 100 kg of small fish. This 100 kg of small fish when eaten give 10 kg of mackerel, a larger fish. Ten kg of mackerel make 1 kg of the big fish tuna. One kg of tuna can increase the weight of man's body by about 0·1 kg.

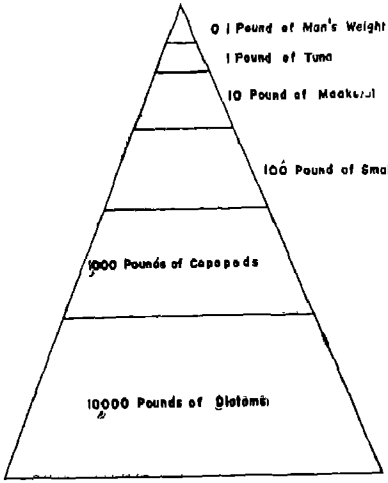


FIG. 33 The food pyramid.

The swimmers of the sea, the Nekton

Above the wide sea floor lies the great column of water like the air above the surface of the land. In this column of sea water many animals live actively swimming, some with real grace and beauty. Though there are several kinds of animals that more or less swim about, the true swimmers are the fishes, the whales, the cuttlefish and the squids.

The majority of the swimming forms in the sea are the fishes. Fishes are animals with a backbone. They breathe air dissolved in water by means of organs called gills. The biggest groups among vertebrates is the fish group. Nearly 40 thousand different kinds of fish are known at present. Fishes have greater range in size than any other groups of vertebrates. The smallest fish, the Philippine goby, is only a quarter of an inch long. It is the smallest known animal with a backbone. The largest fish is the whale-shark and is over 2,000 times longer than the smallest fish. In weight fish range from just three grammes to about 22 tonnes They exhibit a wonderful variety in colour. We can see fishes which are brilliantly coloured like beautiful butterflies and some can emit dazzling patterns of living light. The habits of certain fishes resemble those of man. Certain fish are strictly vegetarians like certain high caste Hindus. Some feed on other fish, while still others have no such preference. Some are very curious in that they catch their food with fishing rods. There are also fishes that burrow like moles, fight like tigers and hibernate like bears. Different types of temperament may be seen among fishes such as nervous, timid, mild, placid or lazy Some are energetic and even bloodthirsty. A few get easily irritated, while others are bold and fearless. Their breeding habits show an almost endless variety. Certain catfish carry their eggs in their mouth until they hatch. Some lay their eggs in special places and carefully guard over them until they hatch. A few give birth to living young ones. But usually the majority of fish lay eggs. Some of the fish lay a surprisingly large number of eggs. A cod lays several million eggs. But all these eggs do not develop to become adult fish. Probably only about one egg in a million laid becomes an adult. Fish are found in all regions of the sea In the open-surface waters swift swimmers are usually found. In the dark deep sea curious fishes with cruel mouths and lights on their bodies are found. The brilliantly-coloured fish are usually found among coral reefs. Flat fish with both eyes on the same side live on the sea floor. Fishes are divided into two great groups based on the nature of their skeleton. In one group the skeletons are made up of a soft substance called cartilage. The sharks, the skates and the rays belong to this group. The members of the other group have bony skeletons and the majority of the fish belong to this group.

Sharks and their relatives: the killers of the sea

Sharks are fierce and savage creatures Some of them are extremely bold and readily attack man These bloodthirsty creatures are a constant source of danger to sea bathers. They can aptly be considered as the tigers of the seas. But all sharks are not man-eaters. For instance two of the largest sharks are harmless to human beings. These are the basking shark and the whale-shark. These giant sharks are not killers. Their food consists of minute plants and animals that float on the surface of the seas. These they filter with the help of special sieves in their mouth. The filtered food is collected in their throats and then swallowed. The whale-shark may reach a length of seventy five feet and will weigh about seventy tons.

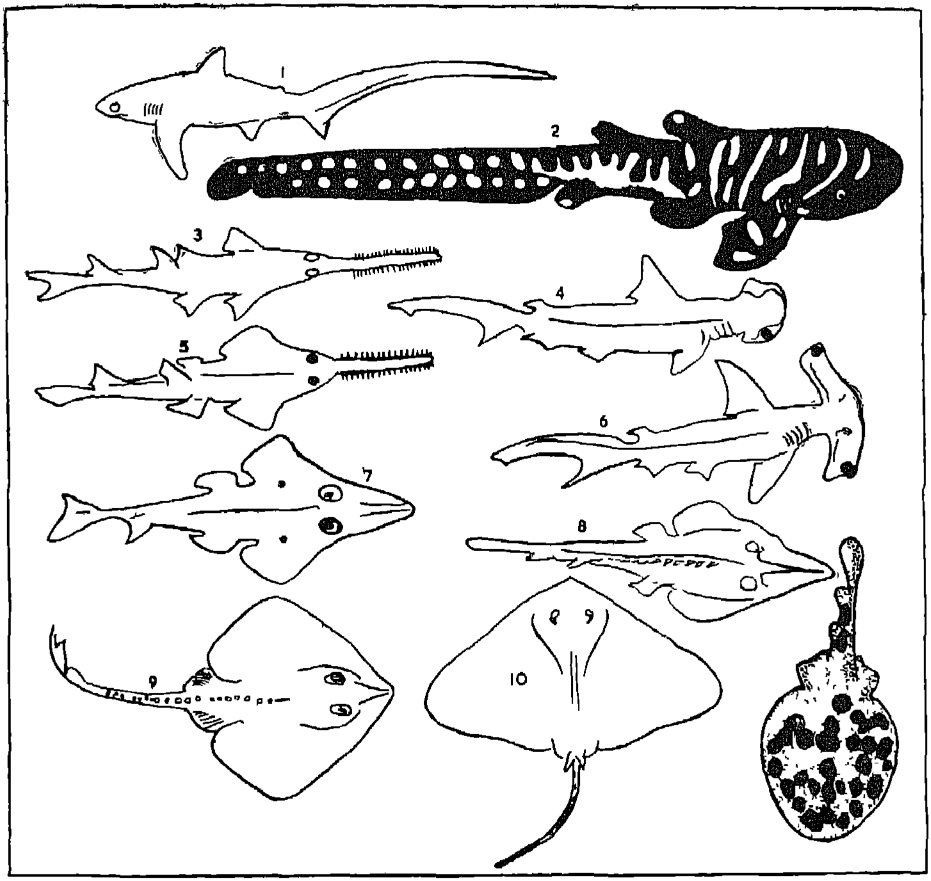


Fig 34 Sharks, rays and skates 1–Shark, 2–Tiger shark; 3&5–Saw fish, 4&6–Hammerhead sharks, 7&8–Shovelnose sharks, 9–Skate, 10–Sting ray, 11–Electric ray

More than two tonnes of this weight is its vitamin rich liver. A remarkable fact about the sharks is that most baby sharks are hatched within their mother and are given birth to. Though sharks are found in all the seas of the world, they are most numerous in the warm tropical seas. Some sharks ascend rivers and enter even fresh water. Sharks are usually found in the upper layers of the seas and they do not generally descend deep into the depths of the ocean. These creatures have a very keen sense of smell and are known to detect blood and offal from long distances. Sharks usually follow other shoals of fishes which provide them with food.

The ground shark of the rivers is one of the most ferocious among Indian sharks. Its body and fins are lead-grey coloured with dull white under side and reaches a length of nearly 2 m. Its mouth is armed with 27–30 serrated teeth in each jaw. The ground shark is very common in the Bay of Bengal and sometimes ascends the rivers to a considerable distance.

Another fierce shark of the Indian seas is the spotted shark It attains a length of about 3½ m. This is a grey-coloured shark with a dull white abdomen. There are several large black spots and vertical bars on the body behind the gill slits. The fins are grey and the eyes large, the teeth are large, compressed and serrated. It is reported that this cunning shark can swell itself up so as to appear like a floating object and attack the unsuspecting prey as it passes by. It is a voracious eater feeding on every thing including sea snakes.

The biggest shark is the whale shark growing as long as 18 to 21 m and weighing about 15 tonnes. It does no harm to human beings since it feeds on plankton. It is very powerful and can dive to great depths. These giants are usually found in the cold waters of the polar seas and not generally found in our waters.

One of the most peculiar of sharks is the hammer-headed shark. Its head is shaped like a hammer and the eyes are located on the outer edges of the hammer-like head. It feeds on small fishes, squids and crabs. Like a little sail its dorsal fin projects out above the water. The Indian hammer-head shark is deep grey or brownish grey above, becoming lighter beneath. The fins are deeply coloured. It grows to about 1 m in length and is very common on the west coast of India during July to March.

The saw fish is a relative of the shark. The common Indian form is greyish-yellow with a whitish abdomen. Its body is shark-like but its most characteristic feature is its snout which is produced into a long, flattened rostrum. The edges of this rostrum are provided with several pairs of strong, sharp teeth. This saw is a terrible weapon used for offence and defence. It swims through shoals of small fish lashing out this saw left and right. Thus it kills many of those fish on which it feeds. It swims near the shore and is known to ascend rivers in search of fish. Some of the saw fish grow to nearly 4 m in length. These creatures sometimes attack man and cut him completely into two pieces.

Skates are flat fishes which live on the smooth shore bottoms. Their colour usually matches with that of the surroundings. The head portion is very much flattened and the snout is very long. The eyes are large. Behind the pectoral fins the body is somewhat subcylindrical in shape The trunk tapers towards the tail. There are several kinds of skates in the Indian seas and they are caught in large numbers on the east coast of India in the month of March.

A curious bottom-dwelling fish is the ray. The ray's body is very flat and leaf-like. This type of body is very advantageous to live on the bottom of the seas. The pectoral fins of the rays have become very much expanded like a flat disc. The tail is long, slender and whip-like. The upper side of the ray is deep coloured and spotted while its under side is light coloured. This colouration blends well with the bottom colouration when viewed from above.

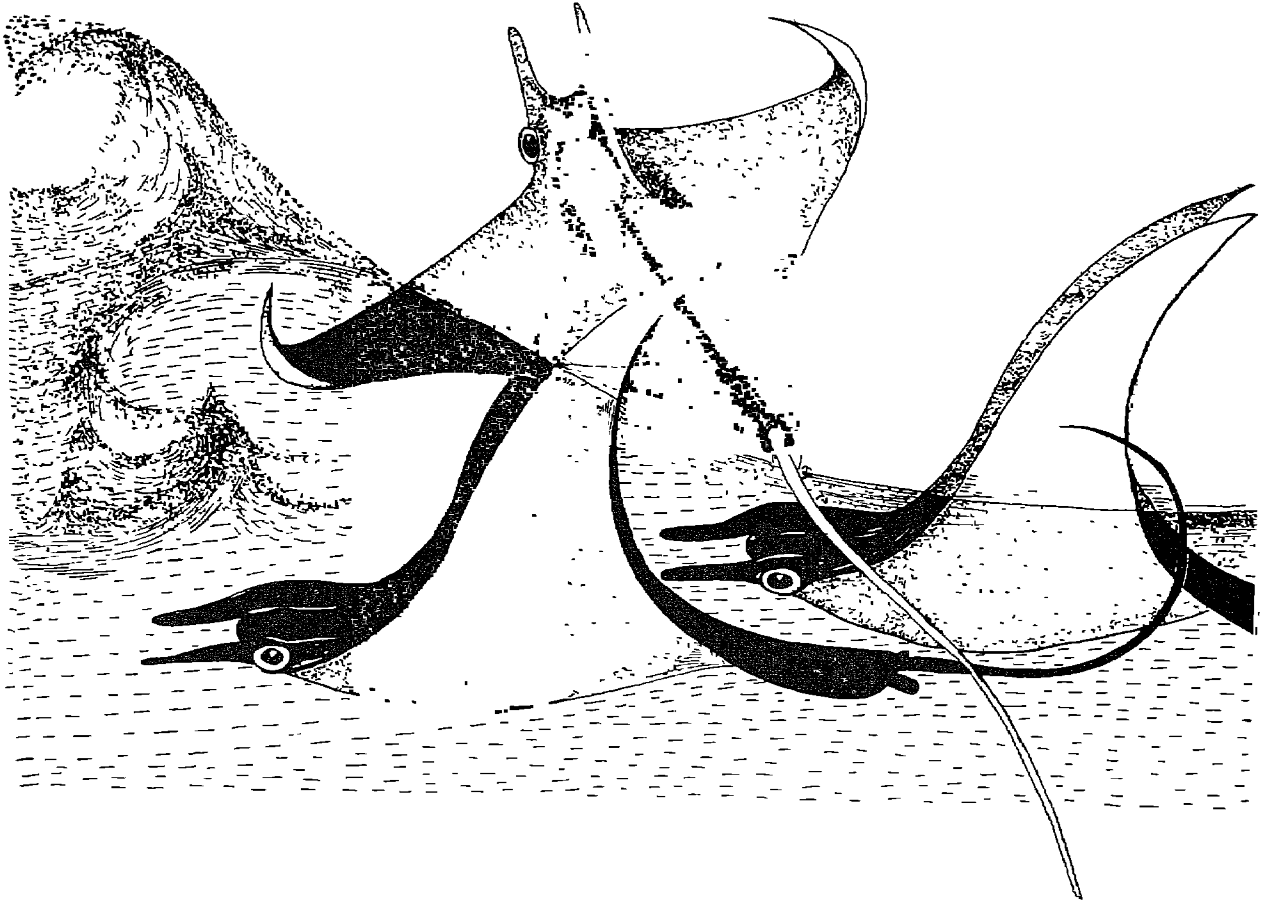


FIG. 35. Rays.

Rays occur in abundance in the shallow waters of the Indian seas. Its long and slender tail is armed with one or two caudal spines near its base. These spines have edges like a saw. When it whips against an object the spines can make a deep and jagged wound which is slow to heal. Some rays attain great sizes and these are capable of wounding human beings with their spines. The small mouth of the ray is placed on the under side of the body. So it cannot attack and eat the prey like a shark. These flat creatures, therefore, lie half burried in the sand on the sea floor and then suddenly encircle a fish. They swim above their prey wounding it with their tail spines. Then they dart suddenly over it and with the help of the expanded pectoral fins convey the food into the mouth. They swim mostly near the bottom and feed on crabs, prawns, clams, worms and fish The common Indian form is the sting ray which grows to a size of about 2 m across the disc. This is lead coloured and is capable of causing dangerous wounds and subjecting the victims to the danger of blood poisoning. Sting rays are sometimes called the 'rattle snakes' of the seas.

A remarkable relative of the sting ray is the electric ray. It is a mysterious member of the ray group. When it is excited it can give an electric shock in self defence. This has the power of benumbing or even killing its prey. The electric current produced by this fish possesses all the known properties of electricity.

Fishes with bony skeletons

The majority of the known fishes have bony skeletons. Some of these fishes are very important for man since they serve as a very valuable item of food. About a third of the fish caught in India from the seas are the sardines. A major part of this catch is from

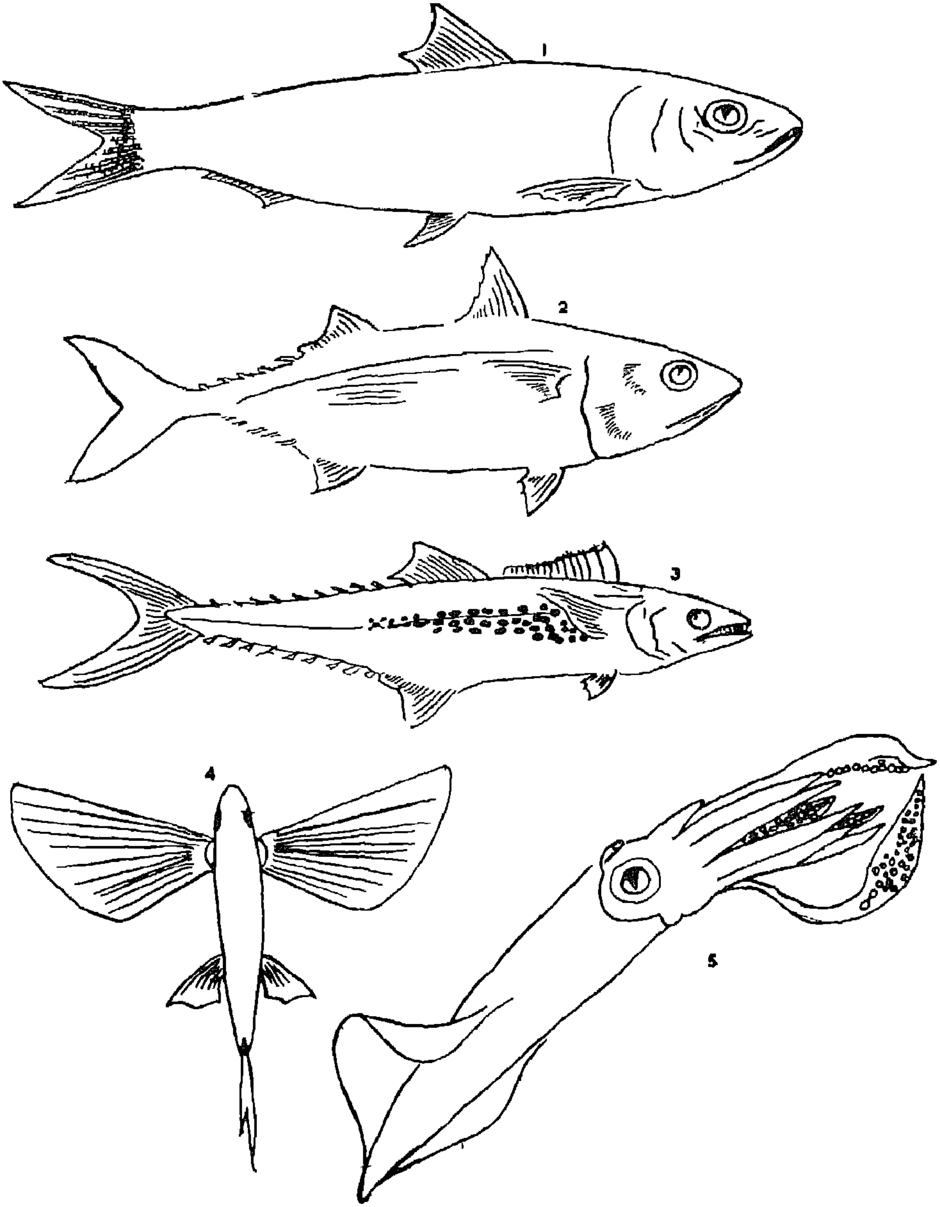


FIG 36. Some representatives of the swimmers of the sea 1–Sardine; 2–Mackerel, 3–Seer fish; 4–Flying fish; 5–Squid.

the west coast of India. The oil sardine is the most important It is bluish golden along the back and its abdomen is silvery with purple dashes. The dorsal and caudal fins are green and the other fins are transparent. Large shoals of the oil sardine appear after the commencement of the south west monsoon along the west coast of India. These shoals remain until about the next March. During September to December they are caught in large numbers. Their appearance along the west coast shows great fluctuation. In some years they are rarely seen while in others they appear in great abundance. This sardine is a valuable food fish.

The mackerels and the seer fishes are also important fishes of our seas which appear in shoals in certain seasons of the year. The mackerel is a swift swimming fish about ten inches long and swims near the surface It is greenish along the back, and the sides and the belly are irridescent. There is a row of sixteen spots along the back. The tail and pectoral fins are yellow. Mackerels are built for speed and their streamlined bodies are adapted for moving swiftly through water. Their scales are very small and their skin is, therefore, velvety to the touch.

Perhaps the most curious and interesting fish is the flying fish. With the aid of its wing-like fins it can glide in the air. Before the flight, it swiftly swims through the water and bursts out at the surface. Then spreading the stiff pectoral fins it gracefully soars like an airplane over the waves for several feet. This it does at an average speed of nearly 56 km per hour before its final plunge back into the water. The pectoral fins do not flap like the wings of a bird. They are just held rigid during the flight and are not used for driving power. These fins form the main lifting surfaces and the tail serves as a rudder in flight While swimming under water the fins are kept

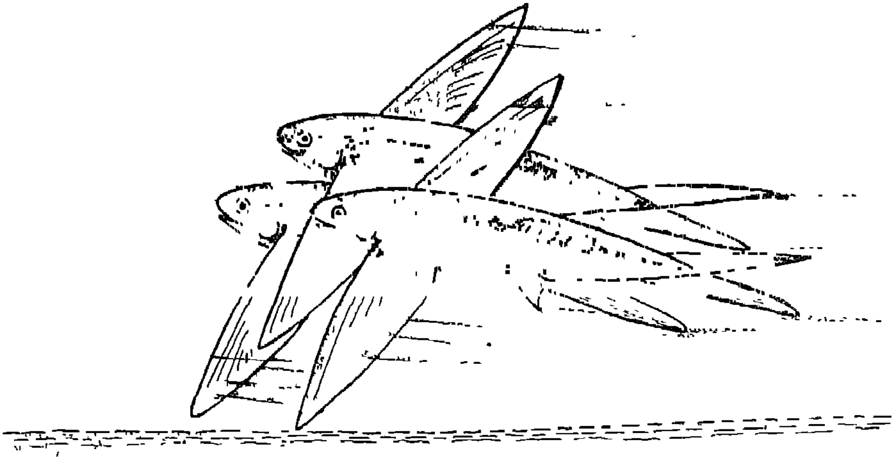


FIG. 37 Flying fish

folded. The lower end of the tail may serve as a sculling oar before the take off.

Usually, the flying fish move about in large shoals. When a steamer passes near a shoal of flying fish these beautiful silvery creatures can be seen rocketing out of the sea surface like a flock of insects. They gracefully soar over the tops of the waves for about ten seconds. But in unusual cases the flight may last for even forty seconds. At the end of the flight the wings are folded and the fish makes a graceful dive back into the water Sometimes it may plop down with a heavy splash. The take-offs are usually made into the wind and in rough weather it breaks through the surface and leaps into the air without any sculling motion with the tail. The flight may not always be in the form of one long leap but may consist of a series of glide-scull-glide in succession. During the night, attracted by the lights, they often land on the decks of boats. Why these curious fish leap out of water is not clearly understood. It is probably to escape from their enemies.

Eels are very long and slender fishes which resemble snakes in general appearance. The most remarkable thing about these fish is that some of them are known to have amazing breeding habits. For example, the European eels are hatched in the Sargasso Sea which lies off the south-east coast of Bermuda. This area is virtually a forest of sea weeds and here each mother eel lays nearly 10,000,000 to 15,000,000 eggs. After laying the eggs the female and the accompanying male slowly sink down and perhaps die. The eggs are very small and round and these soon hatch into glassy, ribbon-like transparent little eels called leptocephali or 'thin heads'. These drift northward along the Gulf Stream towards Europe across the Atlantic Ocean After about three years they reach the coast of Europe Now they are called the elvers. At the mouths of the rivers the males and the females separate. The males stay in the sea near the river mouths but the females swim up the rivers for hundreds of miles. Here in the fresh waters these females remain and grow to maturity. When mature the females swim down the rivers into the sea where the males join them and together they start their long journey to the Sargasso Sea to lay the eggs amidst the weeds where they were born years ago. No other fish is known to show this long and mysterious migration from the fresh water to the deep sea for breeding.

There are fishes in the sea which show remarkable resemblance to certain land animals. The porcupine fish and the cow fish are good examples. The porcupine fish is found in the warm waters of the tropics. To escape from its enemies its body is covered with sharp, stout spines like those of a porcupine. The body can be inflated like a balloon and in this condition it can float like a spiny ball and no enemy can harm it. The cow fish has a pair of spines on its

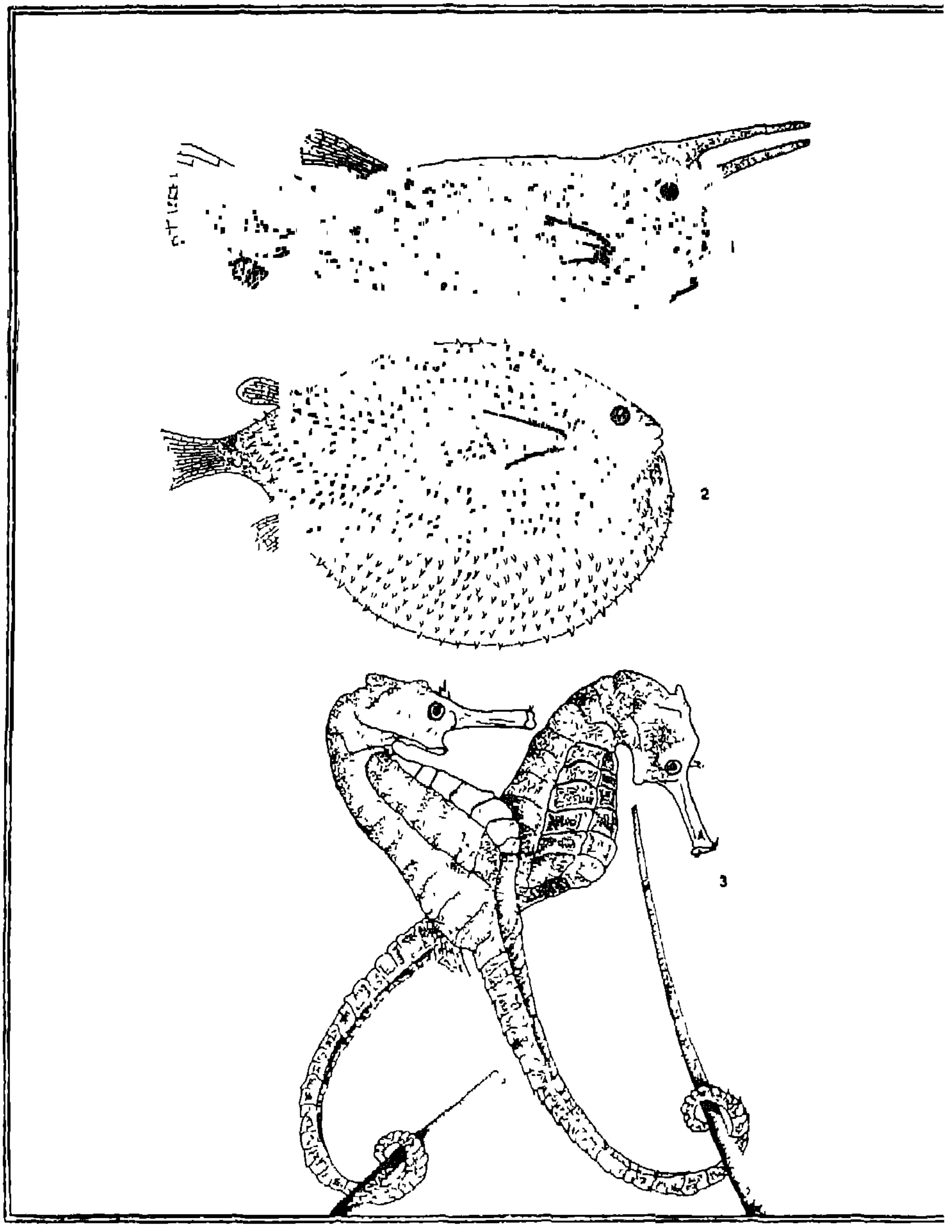


FIG 38. The cow fish, the porcupine fish, and the sea horse

head very similar to the horns of a cow. Its body has a hard box-like protective cover through which the fins, eyes, jaws and tail project out.

The sea horse is another curious little fish looking like a little Chinese dragon, found living usually among sea weeds of the shallow waters. Its head resembles that of a horse and it swims gently with its body upright. Its mouth is at the end of its tubular snout. The tail is used to wrap round and cling on to sea weeds and the fins are small and fan-shaped. In its natural surroundings it is almost invisible and thus escapes detection. An interesting fact about this sea horse is that the father "gives birth" to the babies. The mother lays the eggs in a purse-like brood pouch present on the under side of the male. When the eggs are hatched the little sea horses swim out of the father's pouch.

In the warm tropical seas are found a peculiar fish which can move along rapidly on land. This is the mud-skipper. It is able to walk on land and can also climb mangrove trees found near the shore. When it leaves water it uses the modified pectoral fins to crawl along much like a lizard. When enemies approach, the mud skippers hop, skip and jump rapidly across the mud and swim out into the sea. When the tide goes out they move on to land to hunt for insects. Their eyes are bulging and can be drawn in and pushed out and can be turned in all directions like the eyes of a chamelion. They look very like tadpoles when they rest on rocks or on the roots of mangroves. They can live out of water for long periods as their skins are very thick and as they breathe air.

Two of the most unusual fishes found in the sea are *Benthosaurus* which hops about or rests on its curious fins as if they are legs and *Paralepsis* which swims vertically in water to give the appearance of a small silver javelin.

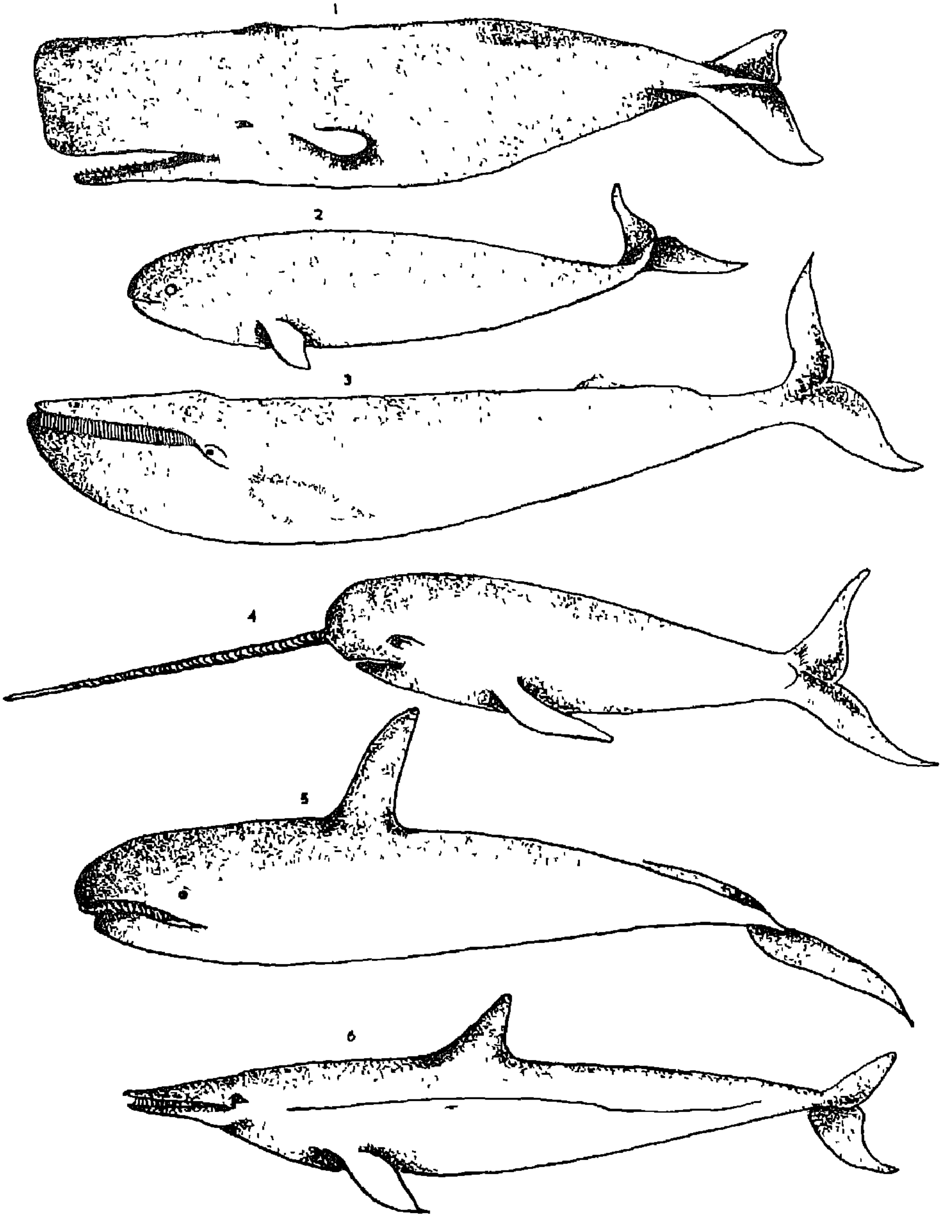


FIG. 39. Whales and their relatives. 1–Sperm whale, 2–White whale; 3–Sulphur bottom, 4–Narwhal; 5–Killer, 6–Dolphin.

Whales and their relatives

Whales are the biggest animals that live on our planet. Though they resemble fish in the general shape of the body they are not related to the fish but are mammals adapted to live in water. They give birth to young ones like the cow or the elephant and feed them with breast milk. Their udders are on their chest as in human beings. The front legs of the whales have been reduced and modified as oar-like organs called flippers and their hind legs have disappeared. The tail is horizontally flattened into an effective swimming organ called the fluke. These giants live in the sea and will be killed if driven out of water. They breathe air as we do and for this they come to the surface at regular intervals. A man can hold his breath for about six minutes but a whale can stay under water for an hour The nostrils of the whale are called blow-holes and are placed rather curiously on the top of its head and not at the tip of the snout. When it breathes it opens the blow holes and exhales a powerful spout of air and spray like a fountain. Like all other mammals whales are warm-blooded. They are very common in the cold waters near the poles. Beneath their skin they have a thick layer of fat called blubber which prevents the loss of heat from their bodies and also diminishes the specific gravity. The ear holes of these huge animals are only as big as our own. The young whale is a helpless creature. It cannot even suck the milk from the mother. The teats of the mother are of the size of our thumb and are placed in slits. But there are powerful muscles that squeeze the milk into the mouths of these baby whales. Whales can effortlessly dive to a depth of even $1\frac{1}{2}$ km where the pressure of water is about 14×10^6 newton/sq. cm.

The whales are classified into two chief categories. Those with teeth and those without them. The toothed whales include the sperm whales, bottlenoses and beaked whales, killer whales, all the porpoises (including Dolphins) and the walruses.

The great sperm whale is a dark, slate-coloured giant reaching about 21 m long with a huge squarish head which is nearly one-third of the length of the body. Whitish patches are found on its under side. It is usually seen in the warm ocean currents feeding on the squids and fish. This is a very powerful whale and is known to sink even ships. Its jaw is armed with cruel pointed teeth and its throat is very large and a man can easily pass through it. With a hissing sound it spouts a column of vapour. The swollen head contains a large quantity of white oil called spermaceti. This is a reserve supply of food. Its intestinal secretion hardens to form ambergris which is used in perfumery. The female gives birth to a calf every two years.

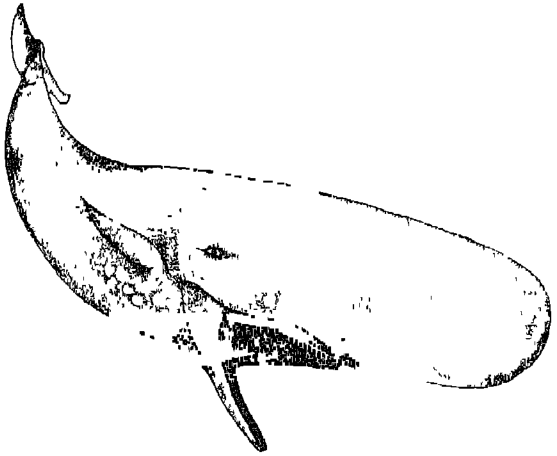


FIG. 40 The great sperm whale.

The most beautiful of all the whales are the white whales. They move about in batches near the shore feeding on fishes found there. They are gentle and not dangerous to human beings. A deep sighing sound is produced when it spouts. Bluish-green when born, they gradually become milk white and grow to a length of nearly 21 m.

The largest animals that has ever lived on this planet is the blue whale or the sulphur bottom. Growing to a length of nearly

37 m this colossus weighs over 152 tonnes. The gigantic nature of this creature will be evident from the fact that its tongue alone is nearly three tonnes in weight. Plankton is the food of this toothless whale. These tiny organisms are filtered through special fringed, flat plates found in its mouth. Sulphur bottom has a greyish-blue colour. Despite the huge size its eyes are only as big as those of a cow. With a whistling roar this giant blows out its breath to a height of nearly 8 m into the air. The rorqual occasionally found in the Indian seas is a relative of this whale.

The Narwhal is a small whale about 3 m long with a slender horn projecting from the front of its mouth. This tusk is straight and grows like a long screw. It is actually a long front tooth and is probably used for fighting and spearing its prey. This curious whale lives in the icy cold waters of the Arctic Ocean. The animal is spotted grey and white all over but becomes white with age.

The killer whale seen usually in the polar seas is a cruel creature. This terrible predator has no fear for man and attacks him readily. These fierce whales are aptly called the wolves of the ocean because they hunt in packs of 30 to 40 like wolves. They generally attack other species of whales in packs, ripping off big chunks from their body, particularly the tongue, with their long, sharp teeth. Small porpoises, seals, and fish are attacked and eaten in large numbers. Killer whales are the most terrible predators of all swimming creatures. These fast swimmers, though ferocious, are beautiful creatures and reach a length of nearly 9 m and have a prominent black fin on the back. The body is black with white patches and white below.

Dolphins are graceful relatives of the whales. They grow to a length of about 3 m and give birth to young ones and feed them with milk like the whales. Their nostrils are placed on top of the

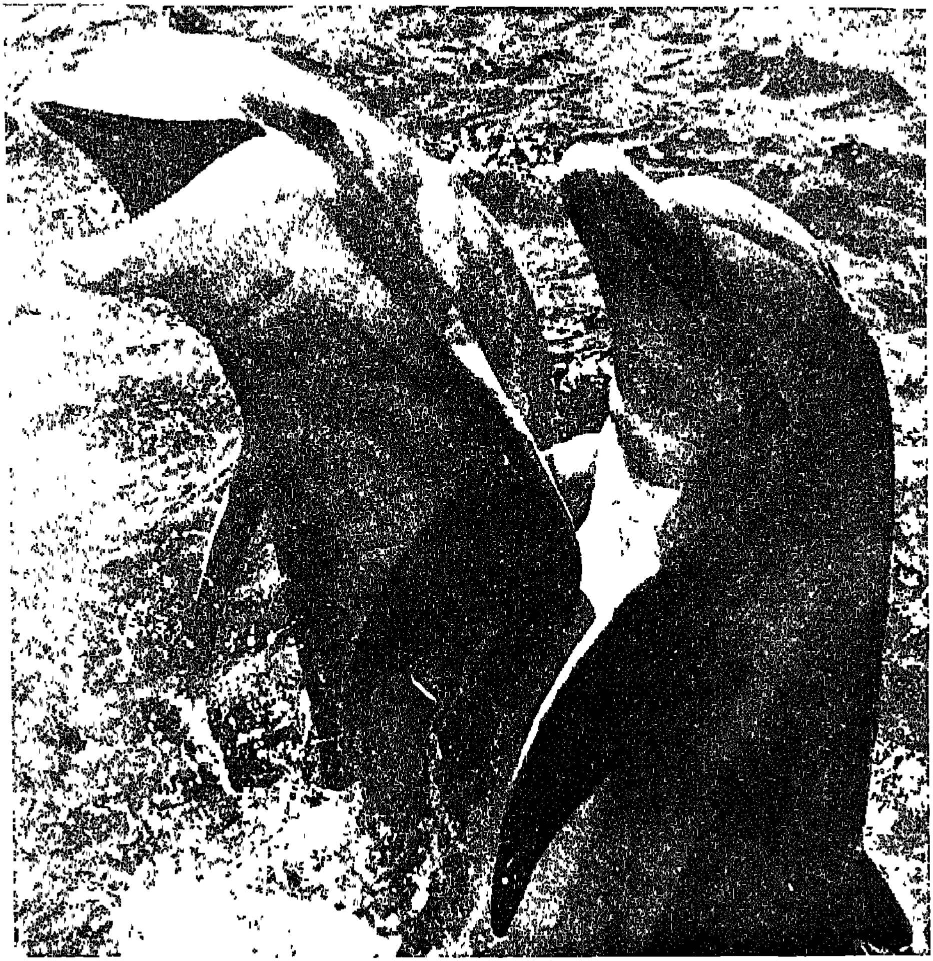


FIG. 41 The porpoise or the bottle-nosed dolphin (USIS photo)

head as in whales and they breathe air. Certain species of dolphins are considered to be intelligent and can be trained to do tricks. Feeding on fish and usually seen in small groups, these pretty creatures can swim at great speeds and sometimes they leap gracefully out of water.

The porpoises are whales of a smaller type just 1 to 2 m long. They usually swim near the surface feeding on fish and can be seen performing somersaults in the waves. They make a peculiar sighing sound while exhaling the air and can imitate human sounds These harmless creatures are killed for their flesh which is considered delicious. The porpoise is also called the bottle-nosed dolphin and is the most intelligent of sea animals. It has an unusually large brain and has the ability to learn.

Like whales seals are air-breathing mammals with the difference that they can come out of water on dry land. Though they can swim and dive with grace their movements are very clumsy on land. When on land they virtually wriggle on their abdomen aided by movements. The nostrils of the seal can be completely closed making them watertight. Its eyes have remarkable optical peculiarities and can be used with equal efficiency both under and above the water. The fur of certain species of seals is very soft and beautiful and hence these are hunted for their skins. During the breeding season each male picks a set of females for his harem. After the birth of the baby seals the family breaks up. Most seals live in groups. They are usually quite harmless, timid and even affectionate animals. They seem to have a rudimentary speech sense and produce various kinds of noise in the form of harsh grunts and barks. They are attracted by muscial notes. Seals can be easily trained and like to be petted and fondled. These affectionate creatures can be trained for shows and circuses and can perform balancing tricks.

Another creature with a whale-like shape is the manatee. Its dark grey body is 2–4 m long and the face is babyish and comical.

The manatee's upper lip is cleft, eyes are small and the nostrils are placed at the end of its fat muzzle. There are no external ears or tusks. This bosomy mammal lives in the shallow waters of lagoons and estuaries where it gluttonously feeds on aquatic plants. While feeding it curiously conveys the food into its mouth with the hands, an action which is almost human.

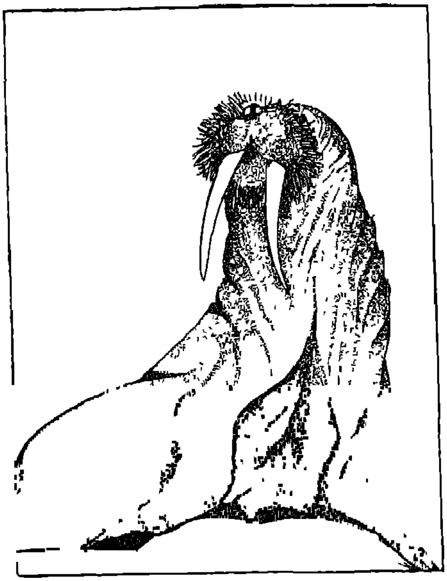


FIG. 42 The walrus.

The walrus is the 'old man of the sea' with a characteristic mournful dignity and is closely related to the seals. It lives in small groups in the icy waters of the polar regions. Walrus when fully grown has a body about 12 feet long and weighs a ton and a half. With its rounded head, a wrinkled nose, moustache of bristles and small eyes, this creature presents the appearance of a fat, disturbed old man. The walrus has large, powerful, downwardly directed, curved tusks nearly two feet long used to climb on ice, to dig up its food, and to fight his enemy, the polar bear. Its hand and feet are webbed. A gentle and inoffensive animal the walrus shows great affection towards its mate and young ones and protects them with great care. Its oil, hide and tusks are all valuable and for these they are ruthlessly hunted.

Dugong, the sea cow, is the well-known mermaid. Its body is somewhat like that of a whale, tail crescent shaped and the head resembles that of a hippo. The sea cow lives in shallow water and grows to a length of nine feet. It feeds on sea weeds with the help of its flexible lips. The mother shows great affection for the calf and feeds it by holding in her arms from the udders on her chest. This she does sitting upright in shallow water. Observing this, the drunk sailors probably got their impression of mermaids half fish and half woman.

The sea otter is a dark brown or black playful creature considered very valuable beacuse of its lovely fur. Feeding on fish, crabs and sea weeds it grows to a length of about 2 m. Its habits are curious and are almost human. The mother nurses her young by holding the baby in her paws and it is reported that she may play with the baby throwing it into the air and catching it. The otter sometimes sleeps and feeds lying on its back in the water. While eating it holds the food in the paws and after the meal washes the face and paws and may even comb the whiskers.

The cuttle fish and the squid are also good swimmers. Unlike the fishes and whales these are animals without backbones and are highly specialized relatives of clams and snails. The cuttle fish has a shell called the 'pen' but it is internal unlike those of clams and snails. A peculiar feature seen in these swift swimmers is that the foot is modified and drawn out into arms surrounding the head. Thus a ring of ten, long, muscular arms provided with sucking discs for seizing and holding the prey is present around the mouth. Well-developed eyes and light-producing organs are other noteworthy features of the cuttle fish. Another unique possession of these animals is a sac filled with a black inky fluid which can be expelled with force to create a dark cloud to confuse the enemy.

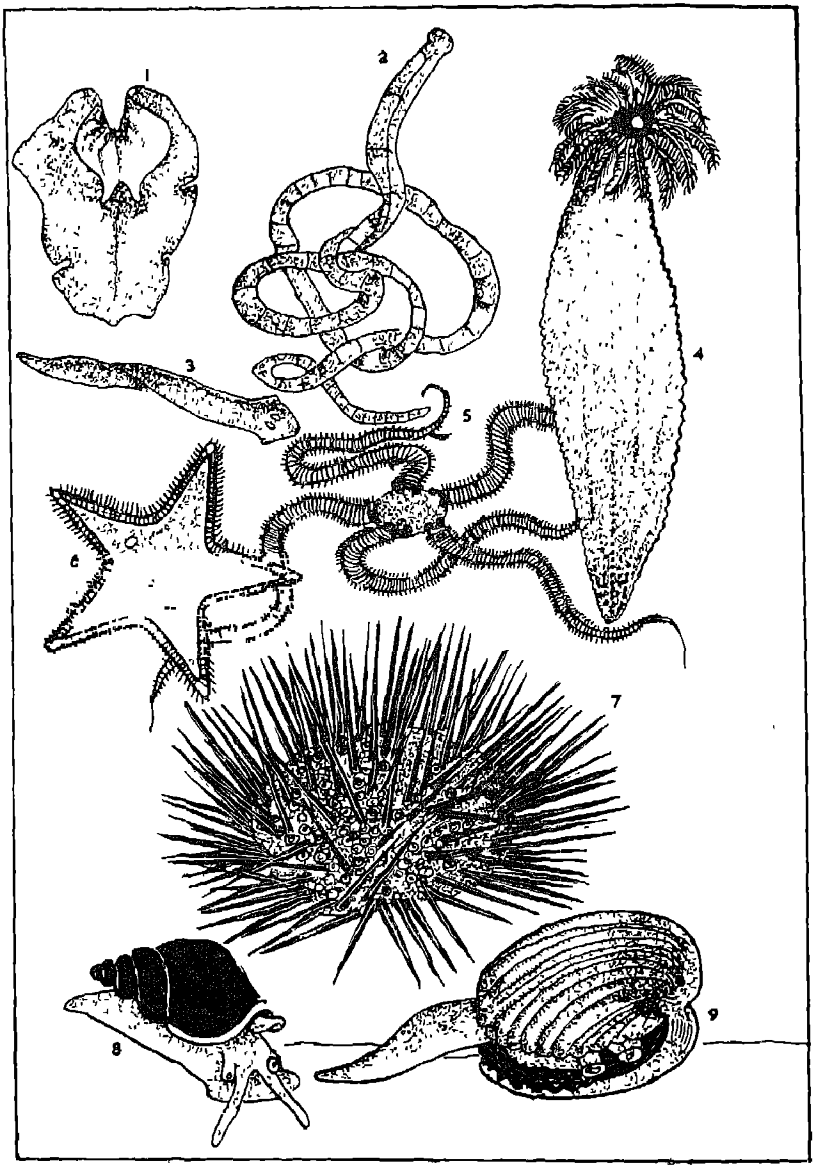


FIG. 43. Some creeping animals of the sea. 1&3–Flat worms; 2–Ribbon worm; 4–Sea cucumber; 5–Brittle star; 6–Star fish; 7–Sea urchin; 8–Sea snail, 9–Clam.

The creeping life

Whereas the plankton and the nekton animals either drift about or swim in the waters, a large number of animals in the sea live a sort of creeping life on the sea floor or on other objects in the sea. An interesting fact about them is that during the early stages of their lives they are found in the plankton. After a short period of drifting life they metamorphose into the adult creeping existence.

The creeping animals include an amazing variety. Some are thin and leaf-shaped and flow like a living film over the rocks. These are the flat worms found among sea weeds and on rocks near the sea coast. Some forms found along the coast of south India are brilliantly coloured. The ribbon worms are either round or flat and may attain a length of 27 m to have the distinction of being the longest of all the invertebrates. They lurk in mud and under rocks and swim about at night feeding on small marine animals, capturing their food with the help of their proboscis. They may be orange, brown, red or purple in colour. The bristle worms are segmented and are the relatives of the earth worms. They are found in sand and under rocks, within sponges or among corals. They swim at night in large numbers especially during the breeding season. Some are active swimmers while others live in crude burrows or in tubes among stones on the sea floor. They seize their food by their sharp, horny jaws and feed on them.

The spiny-skinned animals or echinoderms are not very familiar animals to those who have not gone near the sea. They include animals like the star fishes, brittle stars, sea urchins, sea cucumbers and sea lilies. Built in a circular plan like the jelly fishes this group is most truly marine and not a single one lives in fresh water or on land. A head end and a tail end are not clear since their parts are arranged in a circle around the centre of the animal. The sea stars or the star fishes have flattened bodies and feed on small clams. Sea urchins look like rounded balls covered with spines over the hard skin and live on rocks in shallow water. The eggs of sea urchins are eaten in Europe as a delicacy. A flattened relative of the sea urchin is the sand dollar or the sea biscuit. It lives in deeper water half buried in sand feeding on organic material. The skeletons of sea urchins and sand dollars are found washed ashore on beaches. Brittle stars have long whip-like arms and they creep about rapidly by writhing movements of the arms. Sometimes they live in countless numbers in the form of 'beds' on the sea bottom. The sea cucumbers have soft or leathery sausage-shaped bodies and live burried in sandy bottoms or within corals of shallow water. With the mouth end foremost, they crawl sluggishly on the sand surface and may burrow into the mud and sand of the quiet lagoons along the coast. Unlike their rigid, spiny, brittle cousins—the starfishes or the sea urchins—sea cucumbers have a rather flexible and leathery skin. If roughly handled they will forcibly eject their internal organs and can regrow them later. Some have the curious habit of fragmenting their bodies into two or more pieces by violent contractions when irritated. These are convulsive reactions which are defensive methods. In China and Malaya a delicious soup called 'Trepang or Beche-de-Mer' is prepared out of a particular variety of sea cucumber. The sea lilies look like five-petaled lilies with long stalks and grow on the sea floor.

The clams and the snails belong to the soft -bodied creatures called molluscs. Nearly 100,000 species of molluscs are known Some like certain sea snails are scarcely visible while others like the giant squids and the giant clams are huge creatures. Their bodies

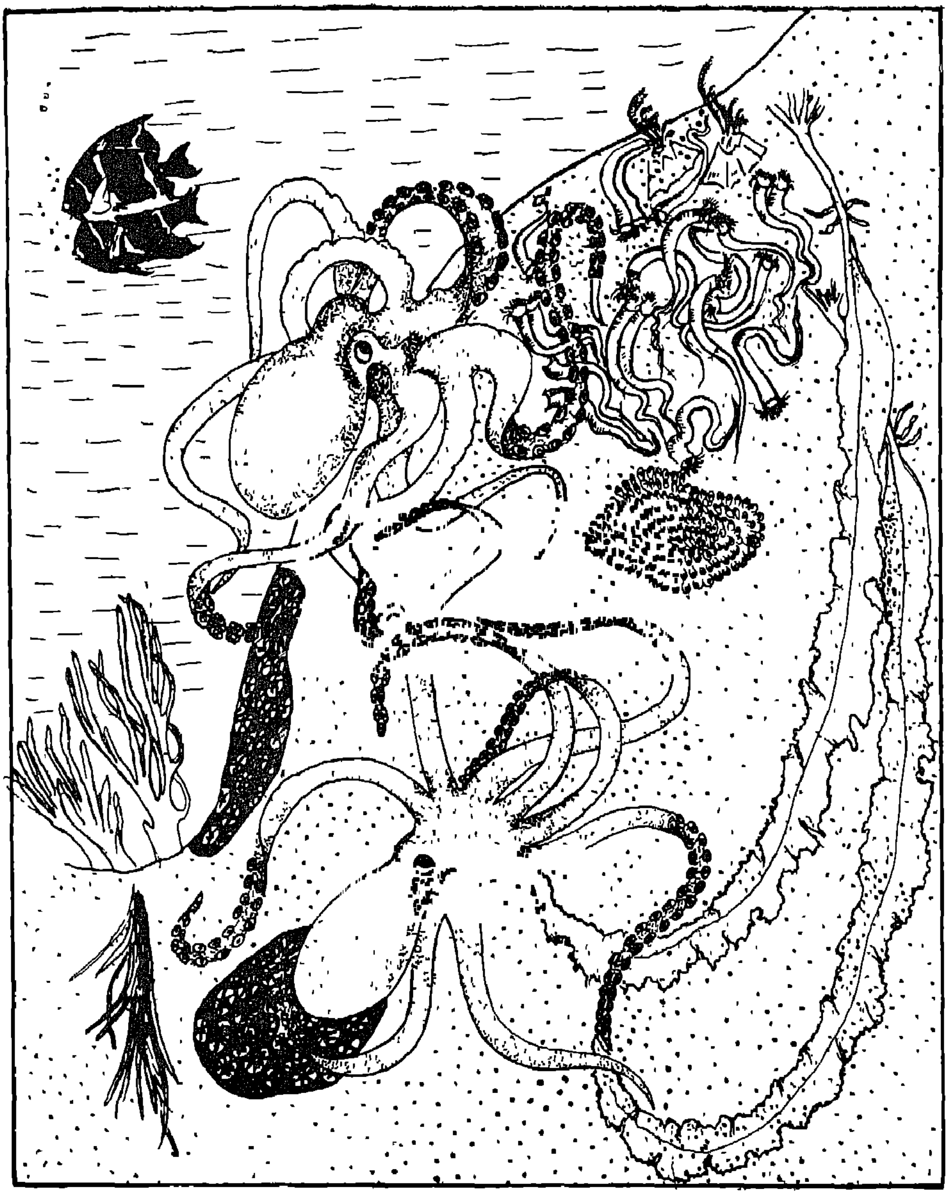


Fig. 44. An under-water scene showing the octopus.

are usually protected by hard shells. The shell of the snail is made up of one piece and is coiled in a spiral manner. They creep about scraping off particles of plant food from the rocks. Some feed on other animals. These snails glide about with the help of their flat, muscular foot. Some can burrow into sand. When danger threatens they can draw their soft, naked bodies into the spiral shell and its opening can be effectively closed by a lid called operculum. The snails have a remarkable tooth-studded, ribbon-like tongue to scrape off plant films from rocks.

Clams and mussels have two pieces for their protective shells. The shell resembles the two covers of a diary. The two pieces are called valves and are joined at a hinge. One or two sets of powerful muscles hold the valves together. Many of these creatures lie buried in the loose mud or sand and draw in water for breathing and feeding through long breathing tubes or siphons.

The octopus, popularly known as the devil fish is a curious distant relative of snails and clams and belongs to the same group in which the cuttle fish and squid are included. The body of the octopus is bag-like with two well-developed lidless eyes and eight long, writhing arms. These serpentine arms are provided with rows of powerful suckers with which the octopus can hold its prey. These creatures are usually seen crawling with the help of their long, flexible arms amidst corals and other growths in the shallow waters of the sea. Rarely they creep out of water and remain on rocks near the shore for long periods. They have also the ability to swim with grace and speed. Some species are small, only a few centimetres in length but there are giant forms in the Pacific Ocean, sometimes 10 metres long. The octopus has great muscular strength and is known to attack and drown divers. But the famous diver

Cousteau has recently quoted several instances to show that it is really a harmless creature. Its food consists of clams, oysters, crabs, etc. Like its cousins, the cuttlefish and the squid, the octopus also has a sac of ink in its body at the end of its alimentary canal. When irritated, annoyed or frightened it violently pumps out a thick, dark fluid from the ink sac which hangs in the water like a mysterious shadow. This trick is probably to confuse the enemy. Octopus is eaten as a delicacy in Japan.

The crabs and the prawns also can be considered here even though they are strictly not creeping forms.

Crabs with their powerful, crushing claws are of many kinds, colours and sizes. Some are small, just the size of a bean seed, while certain Japanese giants may be as wide as twelve feet. The habits of certain species of crabs are curious. The masked crab for instance has the habit of holding a protective object on its back. Some permit their bodies to be covered by algae, hydroids, sponges or sea anemones which help to conceal them from their enemies. Thus the masked crab easily escapes observation.

The dhobi or the fiddler crab is a small crazy, gregarious crab seen usually between tide marks in estuarine areas of our coasts. One of the claws of the male is unusually enlarged into a weapon of defence and of attack. The way it waves this huge claw reminds us of the dhobi beating the cloth on a rock. This habit has earned this crab its popular name.

The mole crabs found along the sandy shores have the habit of burrowing into the loose sand for concealment. The hermit crabs are strange creatures with a twisted abdomen which is kept curled within the empty shell of a snail. The crab creeps about

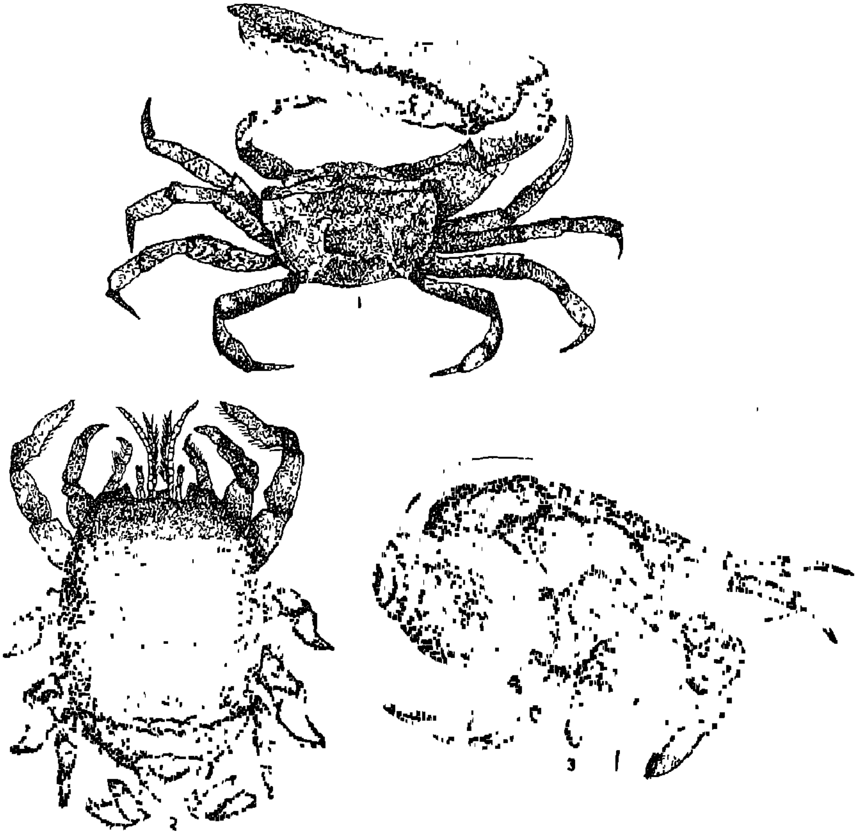


FIG. 45. Some curious crabs. 1–The dhobi crab; 2–The mole crab; 3–The hermit crab.

dragging this borrowed 'house' about with it. When a hermit crab grows too large for its 'house' it must seek a larger one.

The majority of the crabs and prawns are edible. They store great quantities of glycogen or animal starch and of fat, which makes them highly nutritious. *Scylla*, abundant in estuaries, backwaters and mangrove swamps, is the large green edible crab of our coasts. It may be eight inches broad and six inches long. *Neptunus*, the swimming crab, is also a common form found both in the sea and in the backwaters.

There are many species of prawns and shrimps. Some species are found in great numbers in certain seasons and are caught in large quantities by special trawl nets. These are then deep frozen and exported to foreign countries. The lobsters are larger than prawns, inhabiting hard and rocky regions of the sea floor. Some species are beautifully coloured and ornamented. The meat of the lobster is of great commercial value as it is considered to be a delicacy.

The animals that do not move about

There are several animals in the sea which do not move about in the adult condition. During the young stages they are free swimmers and may be found in the plankton but as they grow they bid good-bye to the free life, select a spot and metamorphose into stationary animals. In this fixed condition they draw the surrounding water towards them with the help of the movement of hair-like structures on their bodies and take in the food particles present in it. This water also serves for their respiration. It is rather difficult for the layman to even imagine that some of these creatures are animals at all. They look like weeds or something of that sort. They liberate the eggs and sperms into the surrounding water where

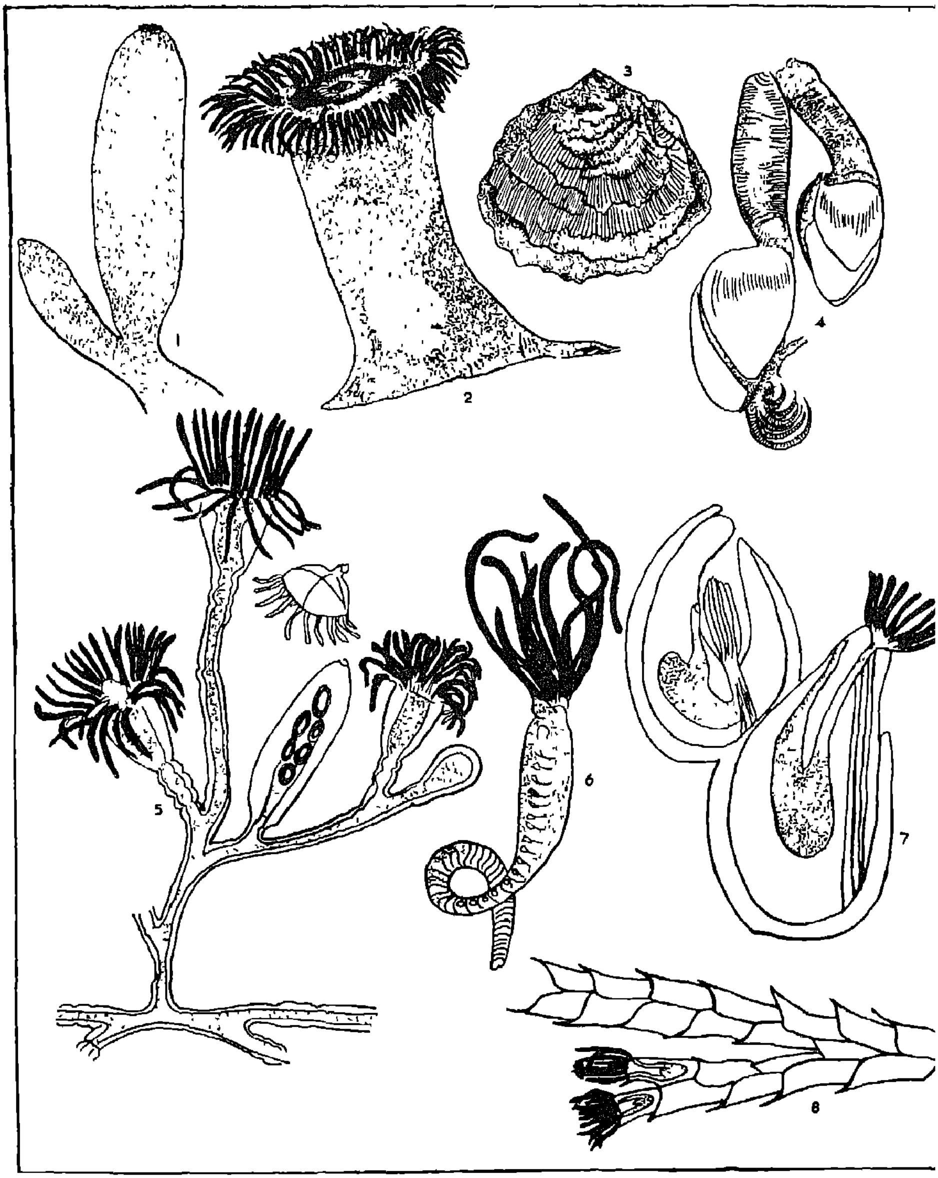


FIG. 46 Some animals that do not move about. 1–Sponge, 2–Sea anemone; 3–Oyster; 4–Barnacle; 5–Hydroid, 6–Tube worm, 7–8 Mos animals or sea laces.

fertilization and the early developmental stages take place leading to the formation of free swimming larvae. These tiny larvae later settle on a suitable object to become the sedentary adult.

Sponges are good examples of such fixed animals. These creatures are very simple types of animals. They live attached after the free swimming stage and their bodies have supporting skeletons which may be made up of a horny matter which is elastic. In some the skeleton is in the form of large numbers of small spicules of many beautiful shapes Sponges are little more than collections of cells. But they are more complex than the protozoans. The cells which form their bodies show some specialization, some for taking food, some for drawing in water, and some for reproduction. The sponges in the adult state are always fixed. Some are simple like little bottles, others grow in colonies on rocks, shells or pilings. They may be flat in exposed places with wave action, assume a tubular, cup or vase-like form in the quiet waters of the deep sea or may be highly branched and tree-like.

The hydroids and sea anemones are also fixed as adults growing on rocks, piles or sea weeds. They are plant-like and fixed and some varieties can produce another type of body which resembles the jellyfishes. In this stage when they can swim freely, they are called medusae. These medusae then reproduce the plant-like hydroids. This is known as alternation of generations, a fixed stage alternating with a free living stage. The flower animals include the anemones, corals, sea fans and the sea whips. The anemones look like flowers some with beautiful colouration and grow attached to rocks and piles. There is a spacious mouth at the free end surrounded by whorls of tentacles which can open like fleshy petals and contract when disturbed. The sea anemones do not have a free swimming medusa stage as seen among hydroids. *Adamsia* is a remarkable anemone which attaches itself to a hermit carb's adopted shell and thus gets free transportation.

Corals are closely related to the anemones. Some can make horny skeletons, others make limy skeletons. The stony corals form great coral reefs, atolls, and islands in the warm seas. The coral anemones live in large clusters. Certain special cells at the base of each polyp can absorb lime from the surrounding sea water and build up the skeleton. These coral polyps grow luxuriously in the warm, shallow, tropical seas.

The sea fans and sea whips have horny skeletons and are found commonly in the warm waters of the tropics. Their polyps are

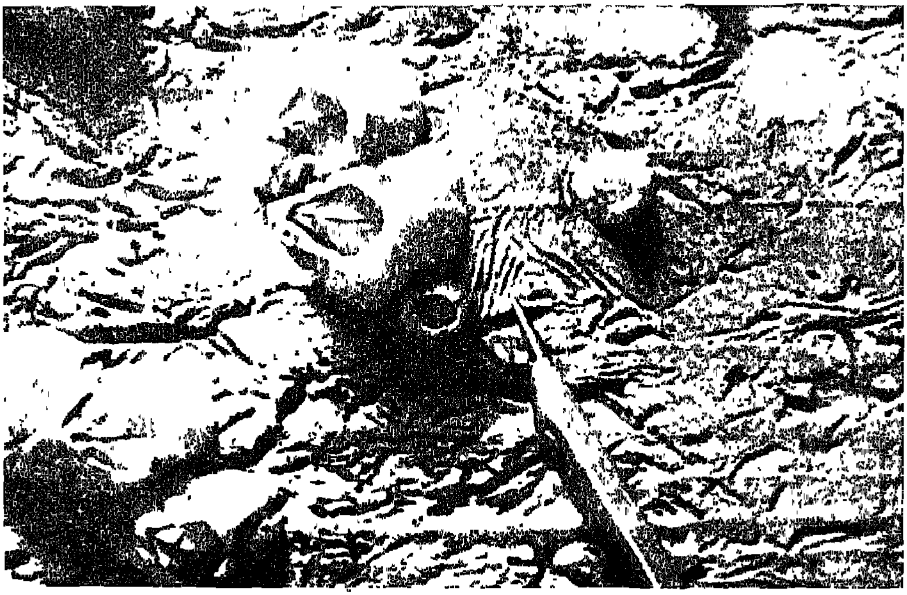


FIG 47a. Acorn barnacles.

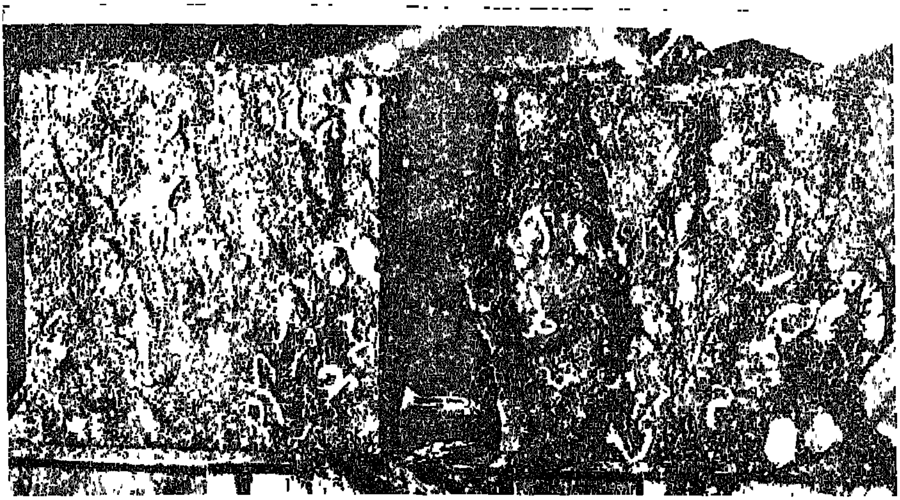


Fig. 47b. White, limy tubes of segmented worms. The small glistening balls are sea squirts.

small with eight tentacles. Their skeletons are flexible and are brightly coloured.

Many worms live an almost stationary life as adults in tubes from which only their head ends emerge. The trumpet worms and the fan worms are segmented worms which build limy or muddy tubes around their bodies. They have plume-like appendages for respiration and for getting food.

The adult barnacles also are attached to rocks, piles or other objects in the sea. The goose barnacles are attached by a leathery stalk but the acorn barnacles are attached directly to rock or to the ship's outer bottoms. Though very unlike any other crustacean in appearance it is a close relative of the copepods, crabs and lobsters. Their eggs hatch into free swimming larvae. These feed, grow and shed their skins changing in form as they grow. After the free swimming life they attach themselves to other objects and are transformed into the adults Their bodies are protected by calcareous shell plates. With the help of their modified, feathery feet they collect the food particles present in the surrounding water.

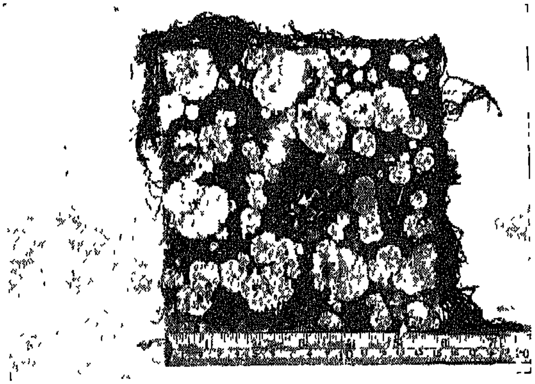


FIG 48 Sea laces.

The moss animals or sea laces or sea mats are a group of interesting animals which live a fixed, colonial life in the adult condition. They appear as plant-like growths and it is difficult for a layman to believe that they are animals at all. Some grow as white, flat, hard patches over sea weeds or rocks, some have a lacy appearance, others have a highly branched and upright form. All these are associations of many animals. Some build horny sheaths and others secrete lime-like corals. These encrusting forms present beautiful mosaics of closely placed compartments. In each compartment there is a small animal.

The oysters are closely related to the clams and the mussels and are fixed molluscs They are usually found in large numbers in estuarine areas. Their flesh is considered as a delicacy in many countries. The pearl oyster is a relative of the edible oyster.

Shipworms are long, slender, worm-like cousins of oysters and mussels. They spend their adult life within the piece of wood they attack. Their shell-valves which cover only the forward end are small and highly specialized. The outer surfaces of the valves

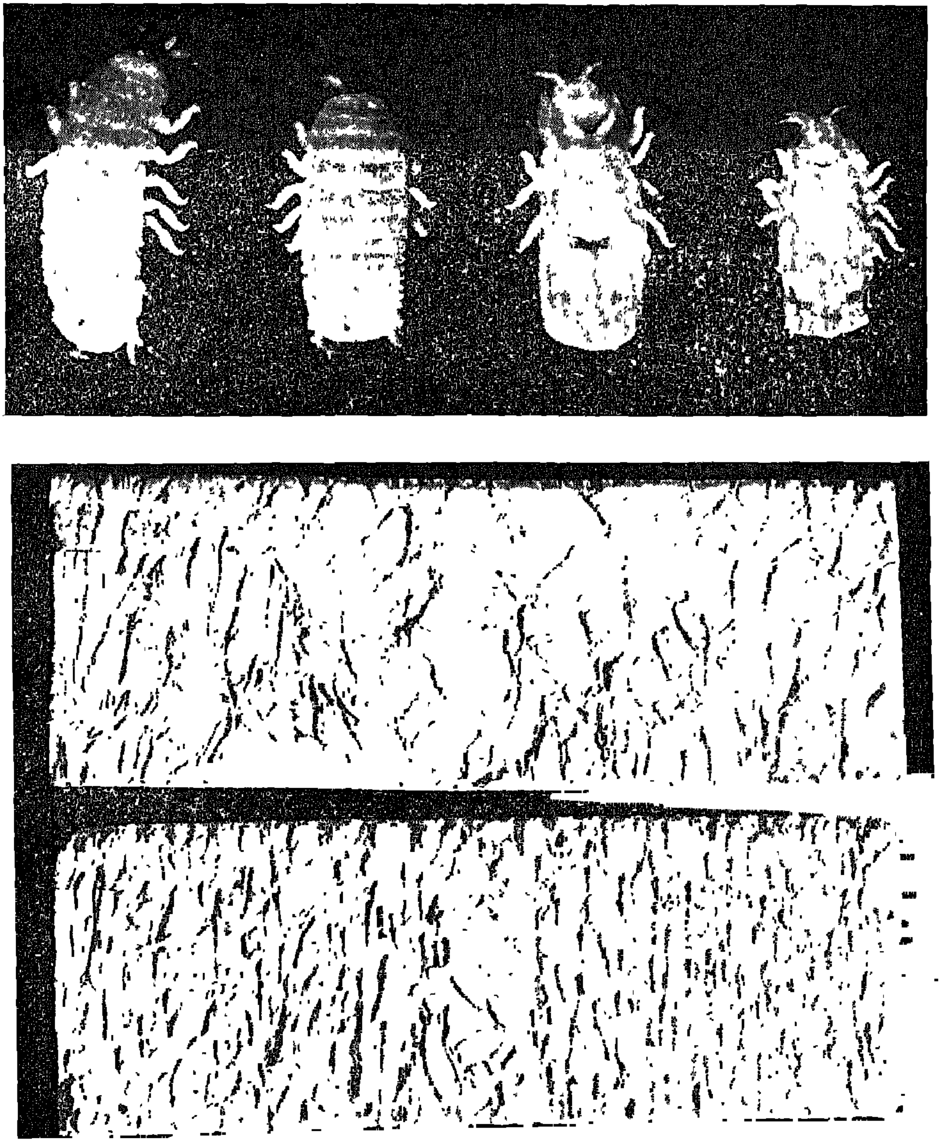


FIG. 49. The termites of the sea. Wood in sea water is attacked by many types of animals in a manner similar to the termites on land. The gribbles gnaw through the wood and give it a lace-like appearance.

are armed with rows of fine, sharp, cutting teeth with which they drill smooth, cylindrical burrows in wood. The shipworms grow as they bore and feed on the saw dust. Mariners of sailing

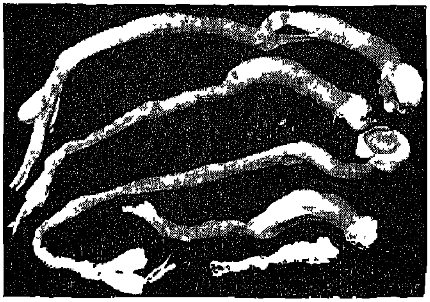
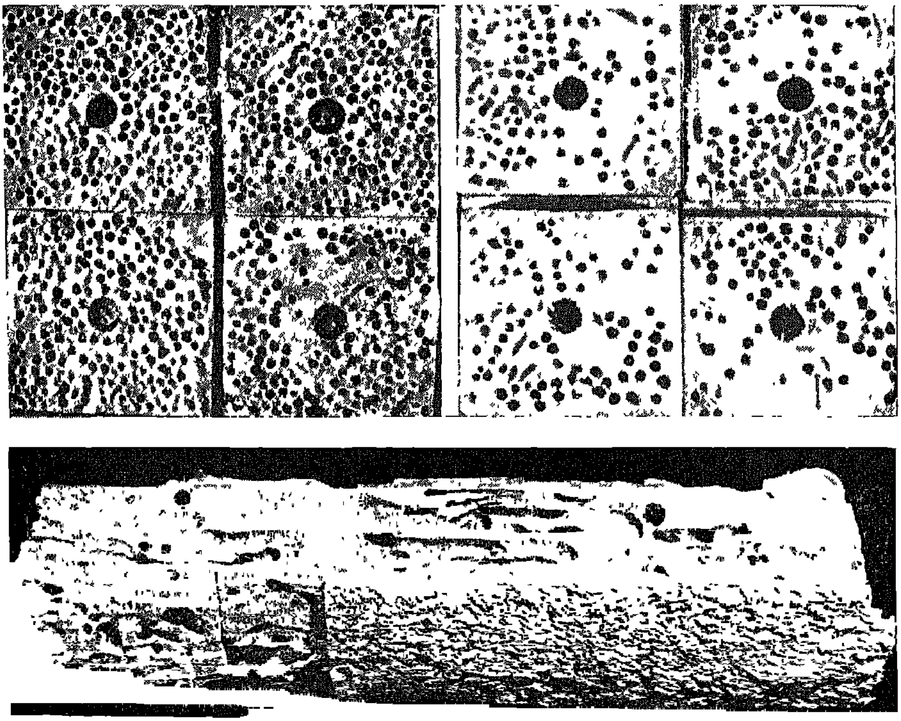


Fig 50a. Shipworms. These are animals related to the clams and oysters. They bore through the wood and feed on this hardy material. Some grow to a length of nearly 1 m and a thickness of the thumb

Fig 50b Timber pieces riddled by the shipworms.



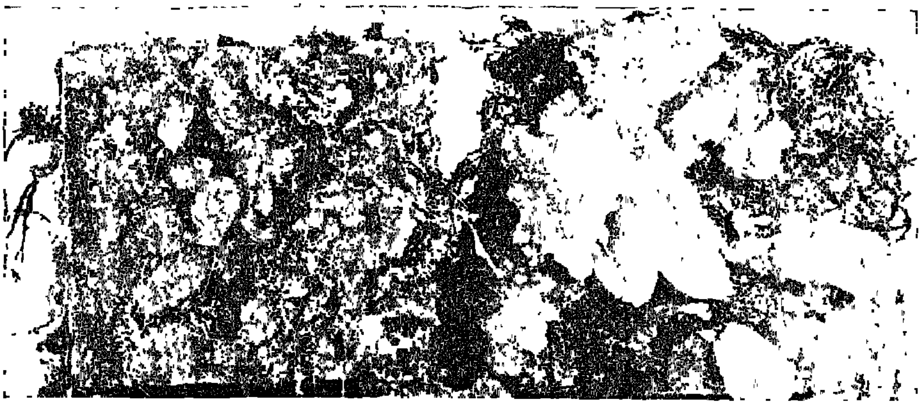


FIG. 51. Ascidians or sea squirts.

FIG. 52 Colonial ascidians. Here many sea squirts live together embeded in a tough, gelatinous substance. Some colonial forms are beautiful, the individuals forming star-shaped clusters of a beautiful violet colour.

boats with wooden hulls were dreadfully afraid of them on account of the destruction they cause to their ships. These creatures even threatened the safety of a nation when they destroyed the wooden dykes of Holland. In our country these pests cause great damage to wooden piers, canoes and catamarans.

The ascidians or sea squirts are high forms of life and are related to the vertebrates much more than any others. They are the fore-runners of back-boned animals. The adult sea squirt is just like a bag and grows in large numbers on rocks, piles, floats, etc. Some are colonial types and many individuals live together embedded in a tough gelatinous substance. Some such colonial forms are beautiful, the individuals forming star-shaped clusters of a beautiful violet colour.

Chapter 8

The Sea Shore

You HEAR THE sea first, the endless roar of the rolling waves dashing against the shore. Then you may smell the salt in the air and feel the coolness against your skin before you actually see the sea. The sea shore is the junction of sea and land. Here the sea meets the land and both meet the sky. The waves roll against the shore with their wash, splash and spray. It is the outpost of survival of the animals and plants of both the sea and the land. It was the high way through which the ancestors of land animals crossed over from water to land in the distant past. The sea shore is very varied in its nature. In some places it is a beautiful stretch of white sand, in others it is in the form of wide mud flats, salt marshes or estuaries. Some shores are rocky. The conditions of the sea shore are very severe. Several forces act on the animals and plants that live here. It is an area of unrest. Here the waves dash against the shore in ceaseless rhythm, the tides press forwards, recede and return in regular cycles. The mechanical force of waves may dislodge the animals and plants. The waves may release dense clouds of sand or mud. In the area between the high tide and the low tide the conditions are very severe and organisms experience extreme conditions twice every day. During the high tide the area gets submerged under water. When the tide recedes the organisms emerge from water into the air. So the plants and animals lead a double life here, emerging and submerging. During the rainy season fresh water floods the area and the animals and plants have to experience this new situation. Thus organisms must be prepared to face the effects of salt water, fresh water or hot or cold air. Enemies of both land and water prevail here. Life, therefore, is not easy in this zone and reveals some interesting examples of toughness and endurance. Yet you can notice many different kinds of plants and animals living here. Almost all the major groups of animals are represented in this interesting zone and it is one of the most thickly populated regions on the earth. Each type of animal and plant prefers a particular area leading to the formation of certain zones. Some prefer the area below the low tide mark, others are found as a belt above this mark and a few towards the high tide mark. Some highly adapted forms can live in all places of the shore. Many books have been written about this strange and interesting region.

Three types of sea shores can be distinguished, namely sandy shores, muddy shores and rocky shores.

The sandy shores

By crossing the little sand hills called sand dunes you reach the sloping, sandy shore. Your feet sink into the loose, dry powdery sand. These dunes are made by the winds which carry the sand from the beach and so they shift their positions according to the winds. Plants are few here on account of the dryness of the sand. The few that are present look like desert plants with thick stems and some are spreading types, clinging on to sand, avoiding the biting sand-laden wind. In this changing world of sand a few rodents, birds and insects may be seen.

Now you walk down the slope into the beach, your feet get the crunchy feel as you step over the damp, packed sand. You come across smooth pebbles and different kinds of shells, some small, others big. The shells show a brilliant display of colour, black, white, blue, brown, red, striped and so on. Some are flat, some like a spiral and a few like the tusk of the elephant. Look at the rotting sea weeds that you see there. How different they look from those of the land. Just step over them and sand hoppers can be seen moving about. As you walk along the shore you come across drift wood, barkless branches, a half buried trunk of a tree, an occasional decaying fish, broken sea shells, pieces of corals, sepia shells, etc. Sand crabs, and hermit crabs in their borrowed shells run away from you to hide in their burrows. To complete the scene you may even hear the distant cry of a sea gull.

In the region between the high tide and the low tide several kinds of animals live a curious, hidden life. Plants are not usually found since they have no good grip on the moving sand. It is a world of concealment for animals. They hide under the sand as the waves recede.

The rocky shores

Conditions of the rocky shores are very different from those of sandy shores. Here the bottom is firm and not loose like sand. The waves dash against it with great power and force Animals living here have special devices to hold firmly on to the rock face, or special cementing substances with which they permanently fix on to the rocks. They have protective covers over their soft bodies to withstand the powerful pounding of the waves. The mussels attach their bodies through special strong fibrous threads, barnacles get cemented on to rocks and limpets hold firmly on with the help of their powerful muscular feet. Sea urchins cling on to the rocks with their tube feet.

Every inch of available space in this region is fully utilized and occupied by animals and plants. You may find them on rocks, within rocks, below rocks, in cracks and in crevices, in holes, in depressions or in tunnels and over sea weeds or within their tissues. There are little hollows on the rocks which get filled up with water during the high tide. These pretty, little pools contain many kinds of sea animals like sponges, hydroids, sea anemones, sea slugs, limpets and many coloured weeds.

Four different kinds of locations are found along a rocky shore for animals to live. Some live exposed on the surface of stones or on weeds that are present there, while others inhabit the rock pools mentioned above. Animals that live exposed on rocks are the barnacles which look like little white pyramids. They sometimes cover the rock completely like a thorny carpet near the high water mark. Other animals present in such situations are the limpets, mussels, sea snails, sea mats and sponges. By turning over the stones we come across a fresh set of animals, sand hoppers, spring tails, ribbon worms, bristle worms, crabs, sea spiders, star fishes, sea urchins and some fishes. In the holes and cracks live many kinds of worms, and rock boring mussels.

The coral reefs

Beautiful and extensive coral reefs and coral gardens are found in the warm waters of the tropics. Corals also form islands and atolls in the sea, the Maldives and Laccadives are examples. Coral reefs are formed by the activity of countless numbers of little sea anemones which live in large colonies and by a particular kind of algae. They have the ability of converting the calcium salts found in sea water into hard stony masses of calcium which are really their

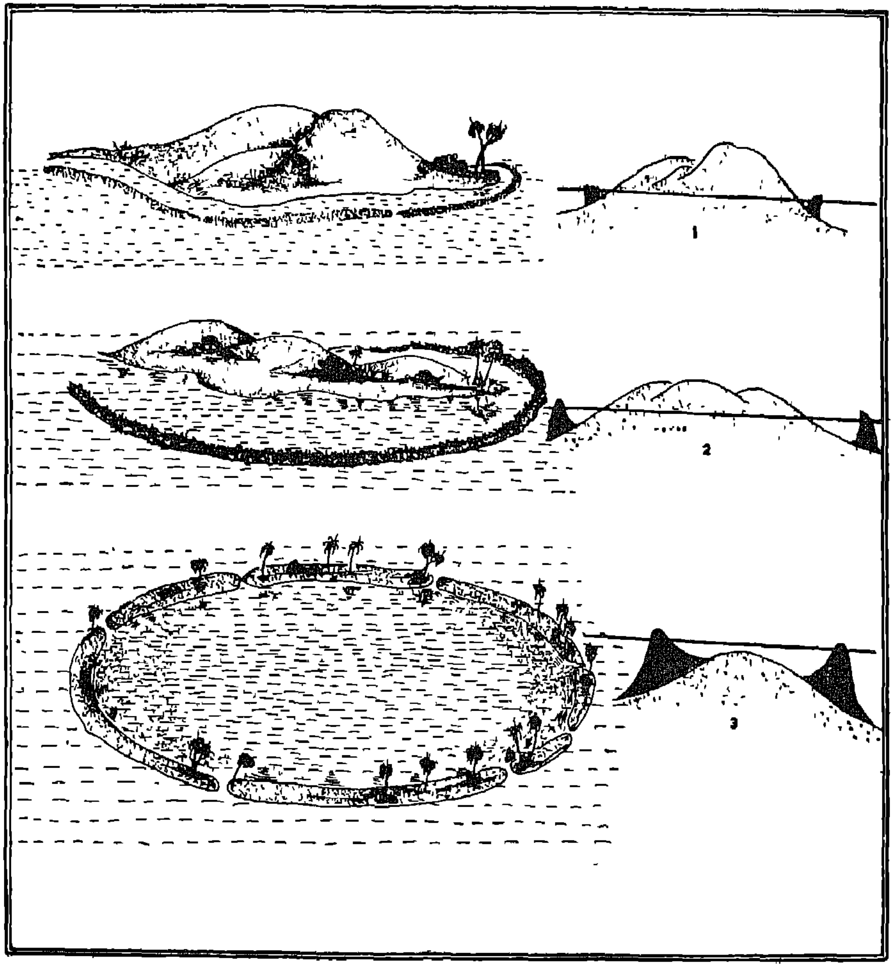


FIG. 53. Coral reefs. 1–A fringing reef; 2–A barrier reef, 3–An atoll.

skeletons. A living coral reef is a beautiful sea garden with corals of different colours such as orange, brown, pink, violet, green, yellow, or white. To add to the beauty of this situation brilliantly-coloured fish and tube worms with their lovely crowns of tentacles are also present. Large sea anemones and delicate sea mats also live in close association with coral reefs.

Coral reefs are found in shallow, warm and clear waters. The greatest coral reef in the world is the Great Barrier Reef off Australia which is nearly 2080 km long. There are three types of coral reefs. The fringing reefs grow around the shores of islands or continents with only a narrow channel between it and the land. The barrier reefs develop some distance away from the land masses so that a deep channel is present between the reef and the land. The atolls are the third type and these are not connected with the land. They are ring-shaped formations, rising above the surface of the sea with a lagoon inside.

Coral reefs look like a fairy land of great beauty. These underwater gardens provide a quiet and pleasant haven for many forms of ocean life. Shoals of brightly-coloured fishes swim about with grace and beauty. The strange-looking octopus or the devil fish lives in little caves and crawls out to look for crabs, its favourite food. Spotted eels lurk, amidst the coral crevices. Sharks swim in and out and sea horses stand upright like sentinels grasping the corals with their tails. Crabs and lobsters scutter along the sandy bottom and look for a likely prey to come along. The polyps of the corals bloom like thousands of tiny flowers. This region when viewed in the subdued light presents one of the most beautiful regions of the sea.

Thus the marginal world of the sea shore is a fascinating region. Its beauty appeals to our imagination. Its variety has perhaps no parallel anywhere else in the world. The rush of water, the surge of the surf, the swell of the tide, the struggle for survival, all combine to make this zone the most spectacular and dynamic region of the ocean.

Chapter 9

The Deep Sea

THE DEEP SEA is dark like mid-night. It is silent and very very old. The pressure is enormous due to the great column of water above. Plants are not present there because of the absence of light. There is very little movement of water. The temperature stands steady without any change and the water is ice cold. Since plants are absent all animals are carnivores or ooze eaters. Changelessness is one of the most remarkable features of this region. There is nothing to mark the flight of time and no indication of days and nights. The march of seasons is not felt in these dark, deep regions. The sameness of the conditions makes it the most monotonous place in the world.

The animals of the deep sea are generally frail and weak. Their flesh is thin and flabby. The beautiful and varied colouration of the animals of the upper zones is not seen here. Some are red, brown or deep violet, others are grey or black and a few have reddish fins. Many deep sea animals have very sensitive and long feelers and slender extensions for the fins to feel their way and to find the food. Several of them have the power to produce light from special organs. Deep-sea animals have wonderful ways for the care of their young ones.

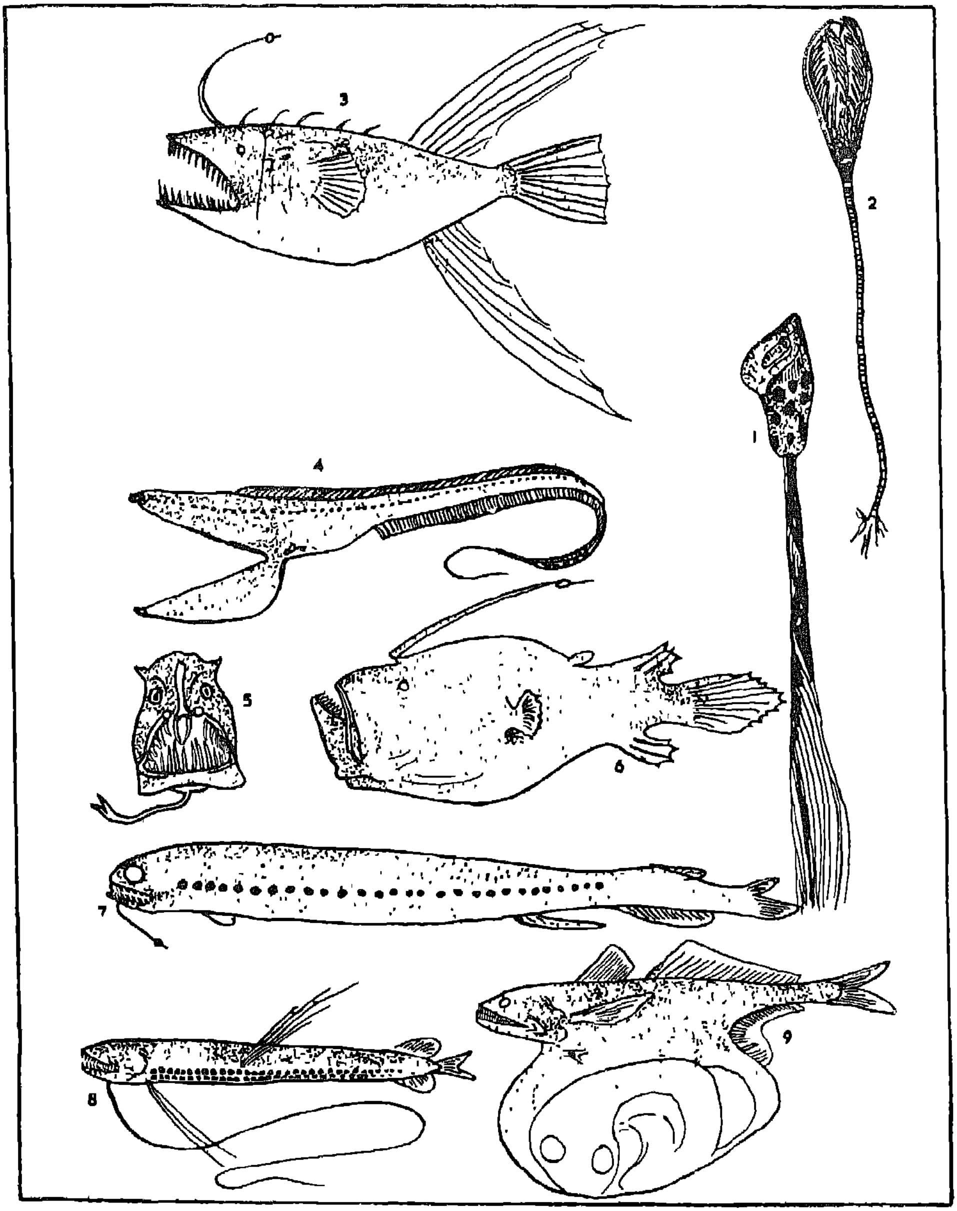


FIG. 54. Some deep-sea animals. 1–A deep-sea sponge; 2–A deep-sea lily; 3–9 Deep-sea fishes.

The most common animals of the deep sea are the sea pens, sponges, sea spiders and sea lilies. Sea spiders have long stilt-like legs to stand clear over the loose mud. Deep-sea fish are carnivores. They are supplied with many large, sharp, needle-like teeth to capture their prey. Some look like monsters with big glaring eyes and cave like mouths. The mouths of deep-sea fish are extraordinarily large. Some species can swallow other fishes nearly three times larger than themselves and store them in their stomach. Despite the darkness of the deep sea, few fish are known to be blind. The eyes of deep sea fish are modified in two directions. They are either very large so as to gather in as much as possible of the dim light or are very small or absent as though the fish had given up the struggle of trying to see in that dark world. The bodies of deep sea fish are generally very soft and the tissues are loose in texture. Dark shades are very common. Luminous organs are present in many deep-sea fish. They are arranged in several rows along the sides and under the surface. Some of these light organs are placed on the tip of filament-like organs on the top of the head or they hang from the chin. These light up the eternal darkness with their bluish, white or yellow lights. The deep-sea creatures are specially built to withstand the great pressure. The pressure of water increases with depth. At a depth of 5 km the pressure would be about 4×10^7 newton/sq cm. When a deep sea fish swims hunting its prey it may sometimes rise too far. As it rises the water pressure decreases. This causes the gas in the swim bladder to expand and the fish rises up against its wish. As it gets near the surface the organs inside the fish swell up and the fish dies bursting like an over-filled balloon.

Chapter 10

Colour and Light Production Among Sea Animals

ANIMALS OF the sea exhibit amazing types and variety of colouration. This is particularly so in the animals of the tropics. The brilliant and varied patterns of colour of the coral reefs and the animals that are associated with such situations would surprise anyone. Besides the possession of colour some have a remarkable ability of colour change. This is a device by which an animal can change its colour to suit the general colouration of its surroundings like the well-known chameleon. Thus, certain prawns, squids and fishes can effectively conceal their body from the notice of their enemies. In some the body colour matches with the background. This is nature's method to protect these otherwise helpless creatures in their struggle for existence. Thus, the sea slugs and certain crabs and fishes are well concealed from their enemies.

Generally, fishes living in the surface waters of the oceans are mostly silver or white with green, blue or black backs. Fishes of the deep sea possess solid colours such as black, brown, violet or red. Usually the colour of an animal is produced from the plants which it eats. In some animals the colours are due to the production of certain waste products which get deposited on the skin to give it characteristic colours.

We are all familiar with the glow worms and the fire flies. But there are many creatures in the sea with remarkable powers of producing a cold and brilliant light. Luminous creatures are very common in the sea. Nearly 1,000 different kinds of organisms have been listed as capable of producing light. Light is produced by animals as a result of a chemical process caused by the oxidation of a luminous substrate called luciferin by an enzyme, luciferase in the presence of oxygen. This animal light is cold because the energy produced is in the form of light only and no heat is produced as in an electric lamp.

Certain dead fish are known to glow in the dark. This is due to the presence of a kind of luminous bacteria in the flesh of the fish. Here the glow is continuous, soft, subdued and almost steady. Of the luminous organisms bacteria are the smallest. Among Protozoa or the single-celled animalcules there is a very famous one called *Noctiluca* or the night light. This animalcule has a remarkable power of light production. When agitated it gives off a flash which lasts for about 1/10th of a second. Countless minute granules present in its body give out the light. The animal itself is pinkish and very tiny and just the size of a pin-point but sometimes they occur in great numbers to give the sea water the colour of thick tomato soup. At night the light produced by these lights up the sea surface to cause 'burning of the sea'.

In most animals the production of light is discontinuous in the form of flashes and many glow only when stimulated. Certain jelly fishes are famous for their bright light production. They appear like round balls of fire. There are also glowing sea pens in which light travels up and down like a flickering flame. Light produced by some twinkles like stars in the sky, while the cold light of others appears like a ghostly glow.

The light produced may be violet or bluish-green as in certain worms, yellow as in certain shrimps and prawns, greenish-blue and powerful as in certain mussels like *Pholas*. The light production may be due to the discharge of clouds of luminous matter into the sea water. In some the lights can be turned off and on at will like a torch light. Many squids have elaborate and complex light organs capable of producing a powerful white or blue or even red light.

Many fishes living in moderate depths have light-producing organs. In deep sea there are certain curious angler fishes with light organs placed in the head region, sometimes at the tip of projections. Usually, the light organs are arranged in rows along the sides of the body resembling the port-holes of a ship at night. Many species of fish, squids and shrimps can flash light spontaneously. In many lower animals the light production is due to the formation of certain substances during the normal activities of these animals. In others light production is to assist in attracting their prey or the opposite sex during the reproductive season. In some it helps to distract or frighten the enemy but the exact purpose is not clearly understood.

Chapter 11

The Indian Ocean

THE INDIAN OCEAN is a vast stretch of water covering 74,049,290 sq km with an average depth of about 4 km.

This Ocean is unique in many respects. The Arctic and the Antarctic that circle the north and south poles respectively have very little connection with inhabited land. The Pacific and the Atlantic are huge, continuous water masses that extend from north to south. But a major part of the Indian Ocean is walled off on three sides by thickly populated land masses. The continent of Asia forms a roof on the north. Its western boundary is formed by the African continent while Burma, Malaysia and the islands that form Indonesia form a wall on the eastern side. The sub-continent of India projects into the Indian Ocean like a triangle.

The Arabian Sea and the Bay of Bengal form two wide northward extensions of the Indian Ocean. The Arabian Sea separates the two peninsulas of Arabia and India. Bounded on the north by Persia and Pakistan, on the west by Arabia and part of Africa and on the east by India, it has two narrow northward extensions, the Red Sea and the Persian Gulf. Socotra and the Laccadives are the islands of the Arabian Sea. The greater part of the continental shelf of the west coast of India has a width which varies from 24 to 104 km. Between Karachi and Bombay the shelf is wider, with

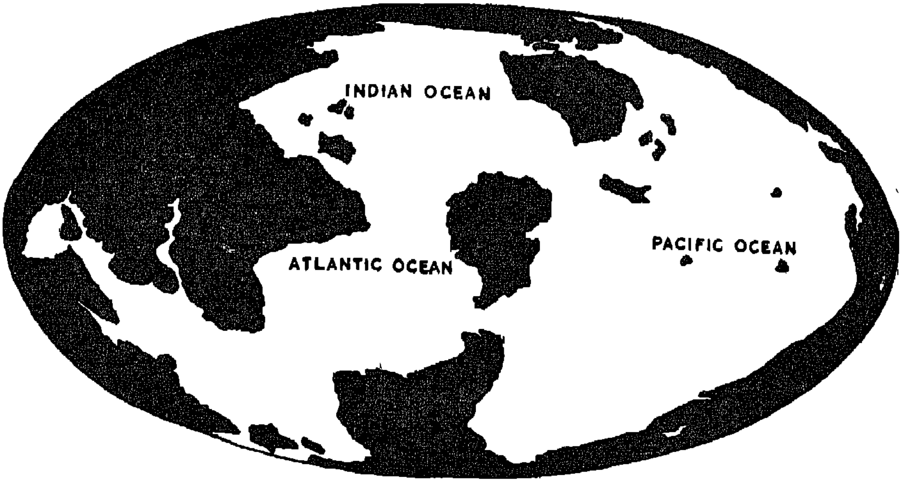


FIG 55 Map of the world showing the nature of the Indian Ocean.

288 km at certain places. The Arabian Sea has been one of the vital seas of the world from the point of view of commerce. Owing to the steady action of the seasonal monsoon winds it had served as a vital highway of commerce for the last 3,000 years for the seafaring nations of the east.

The Bay of Bengal lies between India, Burma and Malaysia. The Bay is also influenced by the monsoon winds and is also subjected to severe cyclonic storms. Ganges, Brahmaputra, Godavari, Krishna, and Cauveri are the important rivers that flow into the Bay from the Indian side. Irrawadi, Sittang, Salween and Tennasserin enter the Bay from the east. Huge amounts of fresh water thus drain into the Bay diluting the sea water. The Arabian Sea which lies in the same latitude as the Bay of Bengal, thus has a greater salinity. This high salinity of the Arabian Sea is also on account of the intense evaporation and the mixing of the high salinity water from the Red Sea and the Persian Gulf. In addition, only three important rivers, the Indus, the Narbada and the Tapti open into it.

The Indian Ocean is one of the least known of oceanic regions of our planet. Apart from its importance in alleviating the nutritional deficiency, hunger, poverty and suffering of the people that live in its neighbourhood, a study of the Indian Ocean is bound to contribute substantially towards fundamental scientific knowledge. This is owing to the unique nature of this body of water which is different from the Atlantic or the Pacific in that it is land-locked on the North and does not connect the Arctic and the Antarctic. The Indian Ocean is a complete ocean system with the great advantage that it is small enough to be studied as a whole and is ideal for the study of several fundamental physical, chemical and biological problems. The oceanic circulation of this area is very different from that of other oceans on account of its peculiar situation. Further, its location offers excellent opportunities for a variety of specialized investigations. These areas are subject to peculiar seasonal reversal of the direction of wind under the influence of the south-west and north-east monsoons twice during the year and an understanding of the various phenomena of this ocean is bound to increase our knowledge of the oceans in general and this area in particular.

We know very little about this great frontier of earth. The science that deals with this 'inner space'—Oceanography—is comparatively a very difficult branch of science owing to the fact that it involves the active collaboration of scientists of different disciplines. The study of the oceans is a slow and arduous task and requires team effort in order to adequately account for the different processes going on in this vast environmental laboratory. The methodic collection of data involves the participation of several large and well-equipped research vessels and hence is very expensive beyond the means of any single country. Therefore, such a study can be most effectively accomplished only through co-operation of scientists on an international basis.

Realizing the great importance of a study of the Indian Ocean the Special Committee of Oceanic Research of the International bodies launched a project, International Indian Ocean Expedition, in 1962. In this unparalleled co-operative endeavour which is expected to continue till the end of 1965 twenty-five countries including India have sent about forty research ships for the collection of data in an organized manner. Besides this many countries such as Burma, Canada, Ceylon, China, Denmark, Ethiopia, Israel, Italy, Malagasy, Malaysia, Mauritius, Sudan, Tanganyika, Zanzibar and the UAR are participating by deputing scientific personnel. In this undertaking over 500 scientists from 28 participating nations will collaborate in the methodic collection and processing of data regarding every scientific aspect of the ocean. Thus the Indian Ocean is expected to receive more scientific attention than has been given to any other ocean at any time.

The data collected so far cover geology, geophysics, physical and chemical oceanography, marine biology including those which would facilitate the location of new fishing grounds. Meteorological data cover, among others, information on atmospheric circulation of the monsoon region as well as energy exchange between ocean and atmosphere. Such data have been collected with the help of airplanes, moored buoys and spar buoy measurements. Information regarding the monsoons is vital to the economy of many countries around the Indian Ocean since they are mainly agricultural, and agricultural operations in these developing countries depend purely on the arrival and action of the monsoons. Meteorological studies will also help to improve weather fore-casting methods which in turn will help to provide adequate and timely warnings regarding tropical cyclones. Development of improved fore-casting techniques is an essential pre-requisite for the development plans in the field of agriculture, exploitation of water resources and flood control programmes and for ameliorating the consequences of weather calamities such as cyclones, severe rains and floods.

Scientists have carried out extensive studies both in the fundamental and in the applied aspects of marine biology methodically from primary production to fish distribution. In the northern and eastern parts of the Bay of Bengal, regions of winter upwellings (natural upward movement of nutrient rich bottom water) have been discovered which are potential fishing areas. Summer upwelling areas representing high organic production and commercially exploitable fish shoals in abundance have also been noted on the western and on the northern parts respectively of the Arabian Sea. Scientists detected at sub-surface levels water masses with low oxygen content on account of the disintegration and oxidation of sinking organisms. During certain times this oxygen-depleted water moves up as a result of upwelling and when shoals of fish enter this area mass mortality occurs due to asphyxiation—a phenomenon occasionally reported from the Arabian Sea.

On the south-eastern part of the Indian Ocean large deposits of ferro-manganese nodules containing low grade iron, manganese copper, cobalt, zinc, nickel, molybdenum and vanadium have been reported. These deposits are formed through the activity of submarine volcanoes, decomposed igneous rock, sea-floor springs and also by rivers which drain into the sea vast quantities of these

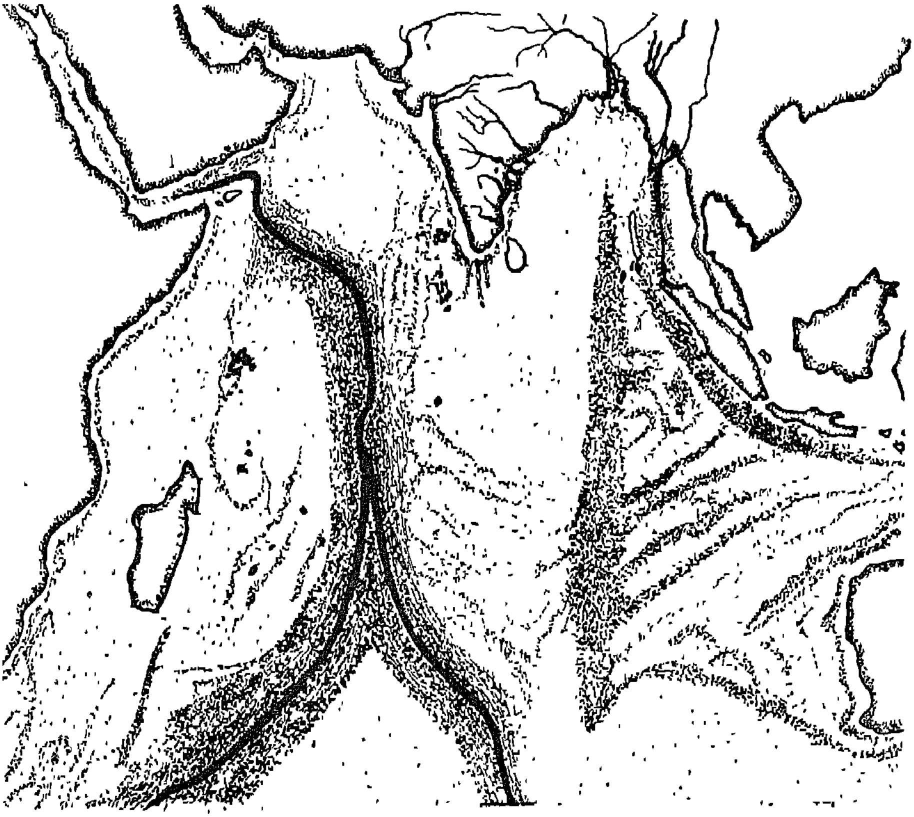


FIG. 56. Details of the Indian Ocean floor.

substances from the land. An object like the tooth of a shark or the earbone of a whale lying at the sea bottom may form the nucleus of a nodule. Calculations show that these nodules form at the rate of nearly ten million tonnes per year and, therefore, represent colossal deposits of these minerals richer than any found on land. Similarly, large quantities of tin ores have been spotted off the coasts of Malaysia, Thailand, and Indonesia and calcareous sandstones near Andamans.

Submarine oil bearing strata have also been located along the east coast of India. If economically exploited these may prove to be of immense benefit for the countries bordering these areas.

The expedition has also brought to light and delineated in detail major features regarding the floor of the Indian Ocean. Hitherto unknown ridges, trenches, canyons and gorges have been discovered. A ridge about 2438 m high and 5760 km long running along the 90° E. meridian in the Bay of Bengal has been located and its details studied. This is the East Indian Ocean Ridge or Ninety-degree East Ridge. Further details regarding the main submarine ridge of the Indian Ocean—the Carlsberg Ridge, which is a λ-shaped underwater mountain—have been gathered. Echo soundings have shown that this ridge is connected with the Mid-Atlantic Ridge on the west and with the East Pacific Ridge on the east. Starting from the Gulf of Aden the ridge is broken or displaced at places and resembles other well-known submarine ridges in general features.

There are vast abyssal planes beyond the mouths of the Ganges, the Brahmaputra and the Indus formed as a result of the discharge of huge quantities of sediments. On the central-east coast of India three canyons about 1300–1500 metres deep have been discovered and named as the Andhra, the Mahadevan and the Krishna canyons. Beyond the east coast of Ceylon also three hitherto unknown canyons have been noted. The steepest continental slope known so far in the world has been spotted east of Ceylon. A precise understanding of the details of the ocean floor is of considerable importance and of naval significance and may well play a vital role in submarine military operations. Further, marine biologists believe that canyons are regions of dense fish population. Trenches are depression of the ocean floor and many such trenches occur in the Indian Ocean. Trenches recently discovered are the Sunda Trench near Indonesia, the Chagos Trench east of Chagos Archipelago and the Vema Trench near Seychelles. The Diamantina Deep off south-west Australia is the deepest part of the Indian Ocean, nearly five miles deep. The importance of these depressions lies in the fact that they may prove to be suitable and safe places for the disposal of radioactive waste.

Physical oceanographers have investigated the currents of the Indian Ocean, and areas of upwellings have been delineated. The existence of submarine counter currents has also been noted and their character recorded.

The United States, the Soviet Union, the United Kingdom, the Federal Republic of Germany, Japan, India, etc. are active participants in this concerted effort and have provided well-equipped research vessels and other equipments besides a large number of scientists who have already participated in the work and will continue to do so in the processing and interpretation of the data. The biological programmes have been significant since they are directed towards fuller exploitation of the nutrient resources from hitherto unexplored pastures and unharvested crops in a search for new frontiers for food. Two international centres, the Meteorological Centre at Bombay and the Biological Centre at Cochin have been established under the Indian National Committee of Oceanic Research. These have given great impetus to the study and growth of marine sciences, especially in India, and a unique opportunity for international co-operation.

Like the International Geophysical Year launched during 1957, this endeavour is yet another excellent example of a multi-

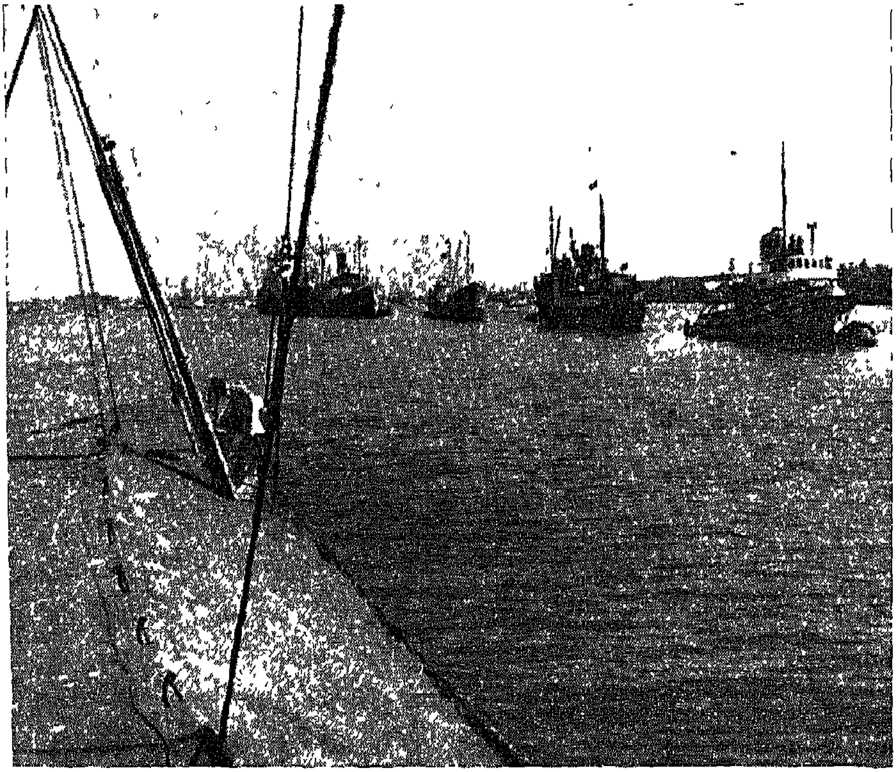


FIG. 57. A view of the Cochine Harbour.

nation effort. This is a glorious evidence of the fundamental, though deep-seated craving of the human spirit, for co-operation and understanding in a world sadly torn apart by distrust, suspicion and conflicts. Let the useful results of the International Indian Ocean Expedition remind us the value of co-operation—the only hope for humanity.

Chapter 12

In Search of Fish

PROBABLY THE most primitive type of craft used for fishing was a simple log of light timber on which the fisherman could sit and keep dry. The progress could be made either by paddling with the hand or with a flat stick which served as an oar. The next step was the log raft, a craft with several logs tied together with lengths of vine, twisted hide or strong ropes. This was certainly more comfortable than a log in the sense that the space available on it was more. A slight modification of this crude craft is the Kattumaram used extensively even today along some parts of the east coast of India. Though the log raft can be fabricated with ease it is clumsy and difficult to operate. Being a non-rigid craft it is suitable for fishing on the rough waters such as those of the Bay of Bengal. The dugout canoe of the Karala coast, as the name implies, is carved out of a log of light timber and the man could sit inside. There are many varieties of dugout canoes such as odams, thonies, etc. This is a better type of craft than the Kattumaram due to the fact that it is streamlined. By fitting an outrigger the stability of this canoe was increased considerably.

The next forward step in the construction of a fishing vessel was the use of several suitable pieces of planks. The planks were fitted with the help of vertical ribs upward from the gunwale of a

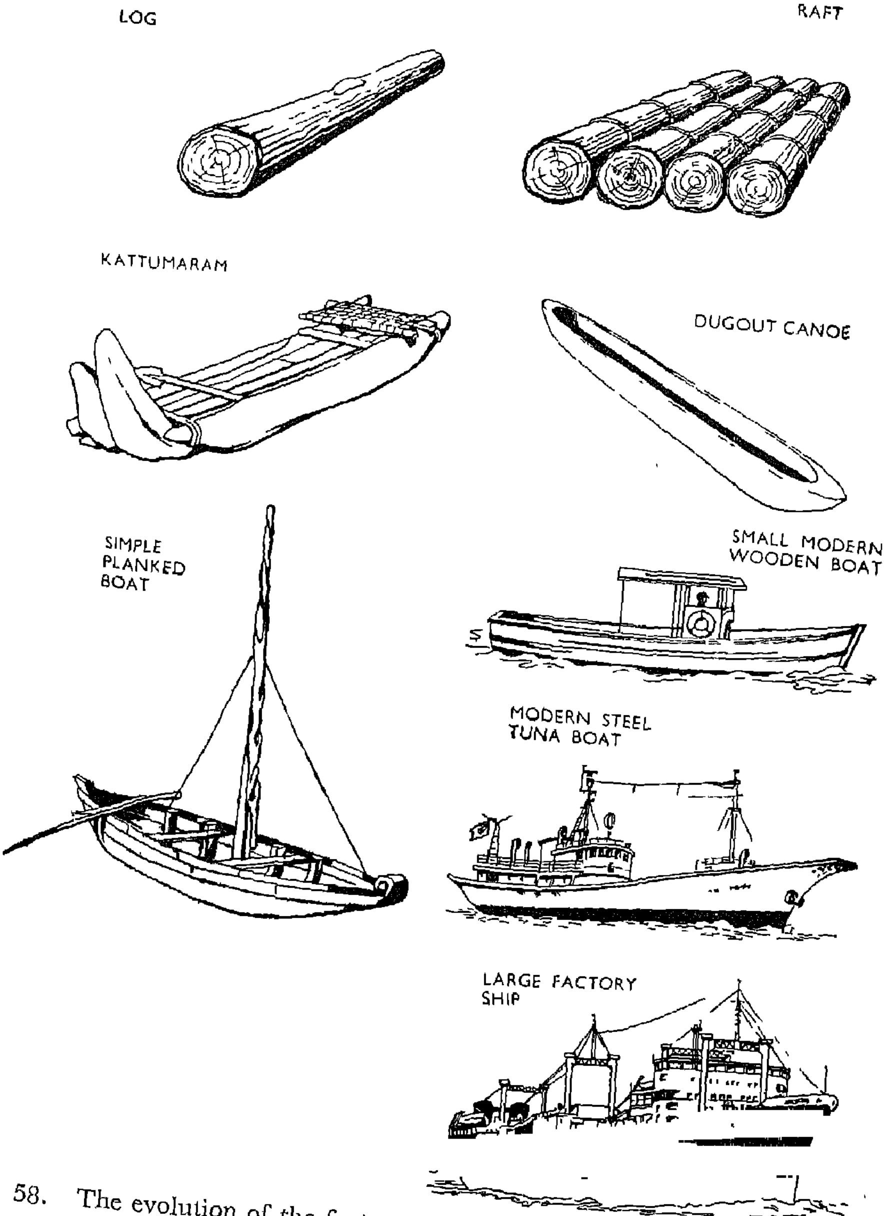


FIG. 58. The evolution of the factory ship (reproduced from 'Freedom from Hunger Campaign News').

dugout. This increased the capacity of the boat and also improved the seaworthiness as a result of the better shape it assumed. The Dinghi and Nauka of West Bengal and North Orissa are of this kind.

The safety of the boat was greatly increased when the deck was made watertight. This and several other improvements encouraged longer trips from the shore to discover new fishing grounds. Through the aid of mathematics and the application of Archimedes Principle to ship building, naval engineers were able to predict how a boat would float even before it was built. The concept of the

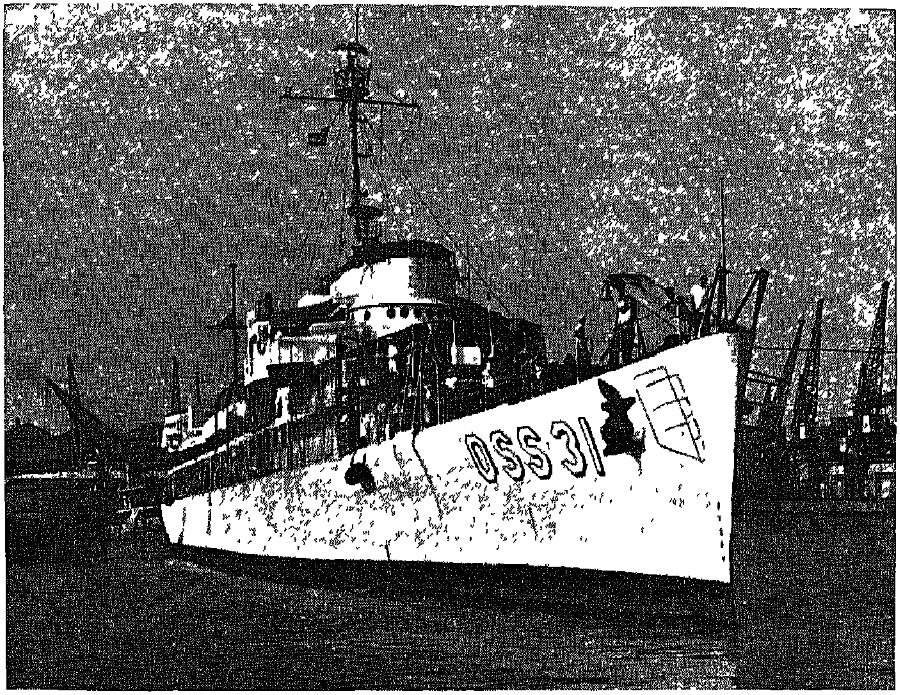
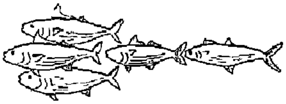


FIG. 59. 'The Pioneer', a modern research ship of the U.S A for oceanographic work (USIS photo).

buoyancy of the material for boat building was given undue importance in early days. This prevented the choice of any other material than wood for boat building. Soon it was realized that buoyancy of the material has nothing to do with the buoyancy of the boat. This led to the use of iron and steel for boat building. The answer for better and easy catches and their proper utilization is mechanisation, i.e. the installation of engines for propulsion of boat and mechanical devices for the handling of fishing gear.

This enabled off-shore fishing and gave a steady power for hauling even very heavy nets. Refrigeration permitted the fishing boats to stay out for longer periods. Better nets increased the catches. Synthetic fibres added to the strength of nets. At present huge factory ships, not only catch fish but also process the catches while still on the high seas.

In the near future many wonderful developments are expected to revolutionise fishing. Novel and new types of vessels are expected to be introduced. Hydrofoils or high-speed crafts which can plane high out of water would rapidly transport fresh fish from the fishing grounds to factories or markets. Hovercraft, a kind of half boat, half flying saucer, would be used for fishing over swamps and shallow waters where wave action is severe, and nuclear-powered submarines would fish under the arctic ice.



Chapter 13

Detectives of the Deep

MAN'S FIRST attempt to catch fish was simple and crude. Probably he tried to catch them by hand or hit them with sticks or stones. Catching these quick, slippery creatures was certainly difficult. It was much more difficult than cornering and killing a wild animal. From crude beginnings he began to try newer and better methods to catch more and more fish. Even the stone-age man was a skilled fisherman. There are evidences to show that he used such fishing impliments as hooks, lines, sinkers, floats and traps. These devices with modifications are used even today for catching fish. Some of the modern equipments and devices for fishing are very complicated and better types of gear are being tried and perfected.

In the seas, the fish have to be found before they can be caught. The business of finding fish is not easy. Until recently finding fish was dependant on the skill and experience of the fisherman. In fact it was a question of luck. Fish in the seas move about usually in large groups called shoals like the herds of cattle that roam on grasslands.

Today fishermen can easily locate shoals of fish with the help of sensitive electronic equipments. One such widely used instrument is the echo-sounder about which we have already studied in an earlier chapter. The echo-sounding equipment helps to spot fish directly under boats and ships. Another more sensitive instrument is the sonar. Sonar is a very complicated and accurate gear. With the help of this, fishermen can literally read the sea not only under the ship but also in front and on both sides. This instrument was developed during the Second World War for locating and hunting submarines.

Formerly most fish were caught near the surface or along the bottom. But with the help of new electronic sounding gear it is possible to catch large quantities of fish from mid water as well.

An interesting method of catching shrimps, etc. that live on the sea floor or that burrow into mud is with the help of tickler chains or with the aid of electricity which drive them into the nets. Electricity gives a shock for the shrimps that lie burried in the mud and send them up into the path of the trawl net.

Russians catch mackerel pike by a novel method. The fish are first of all lured to the surface with under water lights and are then stunned with electric shocks. By means of "electrotaxis" they are then guided towards a suction hose by which the fish are sucked on board. In the Caspian Sea the Russians use light-and-trap for catching sprat.

Electric fishing is expensive at present but there is no doubt of the fact that this will prove to be one of the most promising methods.

Chapter 14

Sardines, Mackerels, Prawns

A MILLION fishermen using indigenous crafts and gear catch about twelve lakh tonnes of fish yearly from our seas. The craft and gear used in our country have been designed to suit local conditions and hence show variation from place to place along the 4800 km of the Indian coast line. On the east coast, due to the roughness of the sea, non-rigid types of crafts such as Kattumarams and Masula Boats are in use. On the comparatively calm waters of the Arabian Sea rigid types of crafts, like dugout canoes, plank-built canoes like the Rampani Boat, and the built-up boats such as the Machwa and the Galbat are employed. The tackle used by Indian fishermen consists of long lines, drift nets, shore-seines, bag nets, boat-seines, cast nets, and Chinese dip nets, etc. The fishing operations are confined to a narrow coastal belt of about ten miles from the shore. The fishermen are generally illiterate and poor. Recently trawl nets have been introduced especially for prawn fishing along the west coast. The most important varieties of fish caught are the sardines, the mackerels and the prawns. Other important fishes of our seas are tuna, seer fish, pomfrets and the Bombay duck.

The oil sardine (*Sardinella longiceps*) is esteemed as a valuable food fish. It is a commercially important species which appears along the west coast in large shoals during the south-west monsoon.

But this fish shows great fluctuation in its appearance along our coasts. This makes the sardine fishery very undependable. The oil sardine is a pelagic shoaling fish and its food consists of plankton especially a species of diatom called *Fragilaria oceanica.* They are caught by boat-seines, drift nets and cast nets from dugout canoes. This fish may grow to a size of 19 cm in three years and spawns only once in its life time. For spawning the oil sardines move out to deeper waters during the period June-August. Many bye-products are produced from the sardines such as fish oil used in soap, leather and jute industries, etc. and guano used as a fertilizer for tobacco, coffee, tea and other crops.

Like the sardines, the mackerels are also pelagic shoaling fish. The commercially important species is *Rastrelliger canagurta* which forms nearly ten per cent of the total catches of marine fish in this country. The major part of this cath is from the west coast where large shoals appear from August to March to feed on the rich plankton in the coastal waters. The main fishery extends from Ratnagiri to Quilon. In this region different kinds of nets such as shore seines, gill nets and boat seines cast nets, etc. are used for their capture. Mackerel shoals can be detected from a distance as "patches, dark with ripples" during the day and as luminescent areas during night.

Feeding on the plankton, the mackerel grows to a length of about 10 cm in the first year and 18 to 22 cm at the end of the second year. Specimens as long as 31 cm have also been caught at times. They spawn when they are about two years old. The spawning is a prolonged process liberating small numbers of ova at each time.

Mackerel is a good food fish and is consumed both in the fresh and in the cured condition. Unlike the oil sardine, the mackerel has a low fat content which makes this an ideal fish for curing. Nearly sixty per cent of the catches are salt cured or pickled and exported to Ceylon, etc.

Prawns and shrimps are also very important groups from the commercial point of view. Large quantities of these crustaceans are landed along the west coast especially in Kerala and in Bombay.

It has been calculated that about ten per cent of the annual catches from Indian coasts is prawn. Of the total landings of prawn, that on the Kerala coast alone is about 30–40 per cent. Owing to the peculiar migratory habits they are caught both from the sea and the estuarine areas. Until recently the major part of the catches were from shallow coastal waters by local fishermen using indigenous crafts and primitive types of gear. The fishery was mainly seasonal when large shoals appeared close to the shore. In recent years owing to the great demand for deep-frozen prawns in foreign countries they are caught by mechanized boats using trawl nets even from deeper waters during the major part of the year. Several methods are used by local fishermen for the capture of prawns. Along the Kerala coast boat-seines are used from canoes in shallow water . Large stake nets are also used for their capture taking advantage of the tide. Other nets used for prawn fishing are cast-nets, drag-nets and Chinese nets. Prawns are also trapped in large numbers during the high tide in the paddy fields that lie close to the backwaters.

Four species of prawns are commercially important They are the comparatively rare *Penaeus monodon* (Karachemmeen) which grows to a length of 30 cm, *Penaeus indicus* (Vellachemmeen or Naranchemmeen) growing to about 20 cm in length, *Metapenaeus monoceros* (Chooden chemmeen) reaching a length of about 17 cm and *Metapenaeus dobsoni* (Thelli chemmeen) which is comparatively small, being only eleven centimetres long. Of these *Penaeus indicus* is the most commercially important species. *Macrobrachium rosenbergii* or 'Konchu' is a large variety of fresh-water prawn growing to a length of nearly 30 cm. During the period September-November they migrate into the backwaters where they are caught in large numbers for freezing and export. Shrimps are comparatively smaller than prawns.

Along the west coast prawns are caught in large numbers from the sea during the monsoon period, but in the backwaters they are caught almost throughout the year, October to April being the best season.

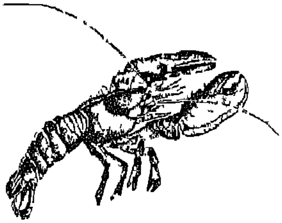
Prawns become mature and usually breed in the deeper waters of the sea. Some species are known to lay their eggs in shallow waters while others spawn only in deeper waters. They breed soon after the north-east monsoon when thousands of eggs are liberated by every mature female. Several distinct larval stages are present in the life history of the prawn. Before attaining the adult stage it migrates into the backwaters where there is a plentiful supply of food materials. Here, feeding on the rich organic detritus present at the bottom, the prawn grows very rapidly. Some species of prawns live up to nearly three years. They have a habit of crowding together in large numbers in the special regions along the Kerala coast known as 'Mud Banks' where the waters are calm even during the monsoon period.

A part of large catches of prawns is used locally either in the fresh condition or after drying. Prawns can be dried either plain or after boiling and may even be pickled in vinegar or weak toddy after shelling them. Boiled and shelled prawns have a good market in south-east Asian countries while deep frozen prawns are exported in considerable quantities to Europe, USA, Australia and Japan. The prawn export which in 1953 amounted to only Rs. 50,000 has in 1965 risen to more than Rs. 70,000,000.

There are several commercially important species of molluscs in our seas. The Indian pearls obtained from the Pearl Oysters are world famous for their excellent quality. Shells of molluscs are used in handicrafts and special bangles are cut from the sacred chank for use especially in Bengal. While certain bivalve shells are used for the preparation of lime used for building construction, etc., others like oysters, some species of mussels, clams, cuttlefish and squids are used as food.

Sea weeds are of many kinds. They grow abundantly in the seas around us, especially along our rocky coasts. They are useful in many ways as food, cattle feed, medicine or manure, etc. Chemicals and minerals can be extracted from them. Some varieties of sea weeds such as *Gracilaria* and *Gelidium* are used for the production of agar, a substance with a wide range of uses in the manufacture of leather, paper, photographic films, laxatives, confectionery, vinegar, cosmetics, tooth pastes, etc. From the weed *Sargassum*, a useful substance called algin, can be processed. Algin is used in the manufacture of cheese, milk powder, cakes, jam, jelly-sweets and fruit-drinks, etc. and also in the preparation of puddings, pharmaceuticals and cosmetics. Mucilages can be prepared out of certain red sea weeds. From these, cementing materials for cardboard manufacture are prepared.

Many varieties of green and brown algae growing abundantly along our coasts or washed ashore in large quantities can be processed into pleasing and palatable foods rich in proteins. They can also be used as excellent poultry and cattle feed. Jams and candies can be prepared from the green algae such as *Enteromorpha*, *Ulva* and *Chaetomorpha*. Dessert jelly, sweet meats, porridges, halva and payasams can be prepared from dry sun-bleached sea weeds like *Gracilaria*. Some sea weeds have medicinal properties and are used for the treatment of diseases like goitre, etc. Sea weeds can also be utilized as a good source for the extraction of several elements like copper, magnesium, zinc, boron, molybdenum, iodine, manganese, iron, etc.



Chapter 15

Towards Better Catches of Fish

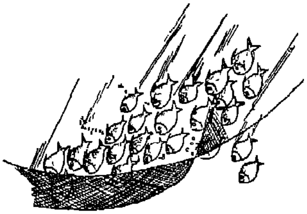
IT WILL BE interesting to examine the ways by which fish catches can be increased in a developing country like India. Against our annual requirements of 4·5 million metric tonnes of fish India produces only about 1·2 million metric tonnes. Therefore, it is essential to explore all possibilities in fishing in order to cope with the increasing demand for food.

Mechanization of the fishing crafts is the ideal way for better catches. In a poor country like India this is an expensive procedure and cannot be undertaken fully, all on a sudden. Replacement of local fishing crafts by mechanized vessels should be undertaken as a phased programme. Since all types of local fishing crafts are not suitable for mechanization, the possibility of providing at least outboard motors should be tried. These outboard motors can usually be fitted on to even primitive crafts and their maintenance is simple and inexpensive. Further, such mechanized crafts need not have harbour facilities. In India there are more than 22,000 indigenous boats in addition to 9,000 dugouts and 20,000 Kuttamarams. If suitably mechanized these crafts can operate farther out in the richer fishing areas of the deep seas and can bring better and easy catches more quickly to the markets. Development must be introduced step by step and stage by stage through a process of gradual mechanization and modification of indigenous boats. Mechanization of local crafts must be considered purely as a transitory phase. New designs most suitable for new fishing methods must be introduced as early as possible. This is due to the fact that real improvement lies in the field of new designs. This must be based on a good knowledge of modern naval architecture.

Along with the improvement of the craft, the gear used for fishing also must be given due consideration. By using modern equipments, it will certainly be possible to increase fish catches to a considerable extent.

The need of expert fishermen is also great. Better catches depend on expert fishermen who can effectively handle the new types of gear and instruments. Without trained fishermen, the instruments become useless. So, schools for training fishermen have become essential. Similarly, schools for training skippers are also necessary because the skipper is the most important man on a fishing boat. The catches depend on his experience. At the same time there must be provision for research which must go on continuously on all branches of marine sciences. This is due to the fact that our information about the oceans is far from complete. We do not know how much fish are present in the seas, where they are concentrated and what are the factors that govern their movements, etc. Our knowledge of the biology of even the important fishes is incomplete. We do not know when is the ideal period for fishing and when it is not. More information is needed regarding the behaviour of fish, and their reactions to different kinds of gear. In short the success or failure of the fishery depends on a full knowledge of the environment or surroundings of the fish including the physical, chemical and biological factors. Knowledge of the behaviour of the fish, their food habits and predators, etc. are also essential. Marine biological and oceanographical studies aim to get information regarding these factors.

All the aspects mentioned above are contemplated in the fishery developmental programmes of the Central and State Governments.



Chapter 16

Preservation of Sea Foods

THE EARLY fishing methods were simple and naturally catches were small just sufficient for the needs. Through improved methods catches began to increase leading to the problem of preserving the surplus catches. Sea foods are highly perishable articles and get spoiled within a short period, especially in the hot weather of the tropics. Fish may remain fresh up to about eight hours after being caught in our climate. Man had been facing the problem of preservation of sea foods for a needy day. This problem is all the more in places where the fisheries are seasonal. Further, the large quantities of fish caught in the high seas have to be transported to markets or to places of scarcity in a fresh or edible condition. From ancient days man had been trying different methods towards this end.

At this point it will be interesting to know how the fish get spoiled. The alimentary canal and the surface of fish contain large numbers of bacteria. These micro-organisms produce certain substances called enzymes, very similar to those produced within our body which help us to digest the food we eat. These enzymes break up the proteins present in the fish flesh into simpler substances such as amino-acids, ammonia and carbon dioxide. Further, fish contain a substance called trimethylamineoxide. Bacteria reduce this substance into trimethylamine which has a characteristic, sharp smell—the well-known smell of spoiled sea fish. Other foul smelling substances such as hydrogen sulphide, indole, etc. are also formed causing the foul odour of putrified fish. Besides these changes, the enzymes of the fish continue to function even after its death. This makes the flesh soft and the rapidly multiplying bacteria attack the soft tissues vigorously. Along with these changes the fish fat gets oxidized causing rancidity.

As early as 308 B.C. the Chinese knew that food stuffs could be preserved from deterioration by suitably pickling them. Other methods such as drying, salting, smoking, etc. have also been widely employed for different kinds of sea foods. Large quantities of the surplus catches along the Kerala coast have thus been salted, dried and exported to Ceylon, Singapore, Burma and other neighbouring countries. Nearly 21 per cent of the catches in India is marketed in the form of dried fish and as much as 19 per cent composed chiefly of sardines, mackerels, seerfish, sharks, soles, etc. are sold as salted fish.

When fish is cured with salt, it draws water out of the flesh and at the same time kills the bacteria that decompose the flesh. Salting thus makes the fish dry to some extent. Since bacteria are unable to thrive without moisture their number is greatly reduced. However, there are certain kinds of bacteria which can live and grow even in high concentrations of salt. These bacteria may infect fish from the salt used for curing purposes. The reddish colour sometimes seen on dry salted fish is due to the infection of these bacteria.

One of the recent methods for the preservation of sea foods is by canning. This process is based on the principle that most bacteria are destroyed at high temperatures under steam pressure. Canning thus makes the fish sterile.

Though these methods help to preserve foods for a long period, they have certain defects or drawbacks. The foods lose their natural colour, freshness, smell and flavour and they cannot compete with fresh foods. Men engaged in the fishing industry have, therefore, been trying to evolve a suitable method which would effectively preserve sea foods, retaining at the same time their original appearance, texture, flavour and quality. Researches in this direction resulted in the development of a new process, the quick-freezing method. This method soon became very popular and is being widely employed on a commercial scale in many parts of the world, especially in the United States. Fresh fish are cleaned and are rapidly frozen by subjecting them to a temperature of –40° C in special chambers. Then they are removed, packed and stored in storage chambers where the temperature is maintained at –18° C. From here the frozen materials are transported in refrigerated chambers of trucks, fish vans or ships to distant markets. It will be seen that in this process a chain of cold storage is maintained from the production centres to the consumer.

This process of quick freezing has been introduced in India only recently. Within the last few years this industry of freezing and export of sea foods has developed into a huge and profitable concern earning large sums of money. Sea foods are now exported to USA, European countries, Japan, Australia and the middle east. In 1964, there were at least thirty firms engaged in the freezing and export of prawns from India. To maintain a high standard of quality, control based on standards laid down by the Indian Standard Institution has been adopted. There is also a Marine Products Export Promotion Council to assist the industry to export more of this costly commodity.

Chapter 17

New Frontiers for Food and Wealth*

COVERING seventy-one per cent of the surface of the globe, the oceans are estimated to contain 1,353,000,000 cu km of sea water which weigh a staggering one-and-a-half million, million, million tonnes. This vast watery world, besides being the abode of thousands of different species of plants and animals which can be economically exploited as a rich source of food and life-saving wonder drugs, is also a huge depository of valuable chemicals and costly minerals.

If world population goes on increasing at the rates recorded in recent years, the present figure of 3,000 million may well be doubled by the end of the century. Whatever the other implications of this astonishing population explosion, one inescapable fact is the inadequacy of the traditional food resources of the land to sustain the vastly increased number of people. In many developing countries the arable land available for cultivation is steadily decreasing under the pressure of urban development. The reduction of farmlands and produce resulting from this process is being offset by bringing new virgin lands under the plough, reclaiming marshy or arid areas and adopting improved methods of cultivation. While hese efforts are commendable and vital to national economy, there s also the imperative need to explore and develop new sources of ood.

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The oceans which abound in fish, shell fish and algae can come to the rescue of man. There are great possibilities in this watery world. In South-east Asian countries, with their steadily increasing population, the sea is an important potential source of additional food. Here the adjacent waters offer an enormous food producing capacity. With the science, skill and means at our disposal it should be possible to increase the production of sea foods sufficiently to cope with the increase in population.

Our knowledge of the oceans has considerably increased in the last thirty years. Science and technology have progressed rapidly and better types of gear have been used for fishing. These have helped to find and catch more fish. As a matter of fact it will not be an exaggeration to state that the progress in fishing in the last thirty years has been greater than that made in the previous 3,000 years. Calculations show that the world fish catch had doubled from about twenty million metric tonnes in 1948 to almost forty-five million tonnes in 1962. The countries that catch the maximum quantity of fish are Japan, Peru, Communist China, the Soviet Union and the United States. Through a scientific approach with international co-operation, it should be possible to save millions of starving people from the pangs of hunger. Present world estimates show that on an average every person gets only ten kilograms of sea food a year. The Japanese are the biggest fish eaters with a per capita consumption of 32 kilograms per year. In England, Scandivania and Holland the average consumption is about 20 kilograms a year and in the United States it is about 5 kilograms on the average.

In India the per capita consumption of fish is as low as 1·8 kg a year, and it is apparent that a substantial increase in this figure would have a salutary effect in easing the pressure of demand for foodgrains and giving the people a reasonably-priced, palatable and nutritious substitute food. The Government of India is alive to the importance of the problem, and a special Fisheries Division in the Ministry of Food and Agriculture has been entrusted with the task of developing the country's marine and inland fisheries. Of special significance is the scientific work—including that of the Indian Ocean Expedition referred to later in this article—being done to explore and locate new fishing grounds and improve fishing methods. For instance, it has been established that the Bay of Bengal has nutrient-laden bottom waters which can enrich the surface water to create conditions favourable for higher fish production. Valuable information has been collected on plankton, ocean currents, etc. which helps fishermen locate shoals of fish with greater accuracy.

Schemes have been introduced for mechanization of fishing craft and suitable designs developed to suit the needs of different regions and conditions of fishing. At present about 3,000 mechanized boats are in operation, and the number is expected to increase to 8,000 in another five years. Mechanization has the great advantage of enabling fishermen to fish in offshore waters which were previously inaccessible, and also results in considerable saving of time and physical effort. Backed by research and coupled with use of improved fishing gear and the other techniques being evolved at the Central Institute of Fisheries Technology in Cochin, it is expected that mechanization will enable India to steadily increase the present annual catch of 1·2 million tonnes by about half-a-million tonne a year. Fish preservation, transport and marketing facilities are being simultaneously improved to cope with the increased production.

Besides the well-known sea foods such as fish and shell fish there are several other substances in the sea which can be utilized as food materials both for man as well as for poultry and cattle. Zooplankton—the tiny animals that drift about in the oceans—may prove to be a good source of food. If this abundantly available material can be economically collected on a commercial scale and processed into pleasing and palatable foods, it can prove to be a rich source of protein food. Marine algae which grow extensively in the sea are other promising sources of food. These weeds have the ability of processing their own food by means of photosynthesis, a process of nature in which sugars and other basic foods are formed in plant tissues containing the green pigment chlorophyll in the presence of sunlight. The aquatic plants have also the ability to convert the energy of sunlight into proteins nearly ten times more efficiently than land plants. Calculations show that algae farming can be several times more efficient in energy utilization than is the average agricultural crop like rice and wheat.

Algae can also be the source from which valuable fodder for livestock can be obtained or they can be processed as rich ingredients of mixed cattle feeds and even as excellent palatable human foods. Certain species of algae are useful for extraction of medicines while others can be used as fertilizers. Multiatom solid alcohols, ethers, vinegar, nitrocellulose, starch and gel agents like agar—agar and alginates can also be processed from marine algae. There are, however, certain practical difficulties in harvesting them economically. Many of these algae are diffusely scattered and when present in substantial quantity appear only as a thin soup in the upper, lighted regions of the oceans.

The sea bottoms, especially in the tropics, contain huge amounts of organic fertilizers. These fertilizers accumulate in the cold, dark floor of the deep sea when animals and plants die and sink to the bottom. The dead bodies are partly eaten by animals that live there and the rest undergo rapid decomposition through bacterial activity and transform into soluble substances that can be used by plants. But in the dismal darkness of the deep sea no plants can grow.

Plants grow well only where there is light; they are seen only in the upper layers of the oceans where sunlight penetrates. In the absence of plants, fertilizers accumulate there without being used. But if this water is brought to the surface by currents or vertical movements of sea water such as convection currents, wind mixing and upwellings, these fertilizers become available for the plants there. In some regions of the sea there are regular upwellings-rich plant growth areas. To graze on these tiny plants, zoo plankton composed of small marine animals gather and attract large shoals of fish which, in turn, feed on zoo plankton. Such regions are excellent fishing grounds. It seems possible that new fishing grounds can be created if the rich bottom water can be brought up to the surface.

In colder seas the bottom water is regularly brought up seasonally during winter when the sea is virtually 'ploughed' through natural phenomena. This natural process enables the surface layers to get periodically fertilized. These regions contain greater concentrations of fish than in the tropics where no such mechanisms exist to bring up the nutrient-rich water from the bottom. This is the reason for the comparatively poorer catches from the topics. Scientists are working on this problem with a view to finding a cheap method for stirring up the deeper parts of the oceans and bringing to the surface fertilizers which can promote organic production Taking advantage of the slight difference in temperature and salinity at the top and the bottom, vertical pipes are being employed to raise water from lower levels. Another method suggested is to set up a large heat source such as an atomic pile at the bottom to produce vertical convection currents to displace the nutrient-rich bottom water. But these are very costly procedures at present.

Sea water is a unique solution with a very small quantity of everything dissolved in it. Water being an excellent solvent every drop that falls down as rain takes up an extremely small quantity of mineral and the waters collect, form rivulets and then rivers and at last reach the oceans. After reaching the sea the water is again lifted up into the air by evaporation by the wind and the sun to form the clouds, leaving behind a great quantity of minerals in the sea. Again, the clouds burst into rains and the process is repeated. This is the water cycle. Each year some 333,000 cubic kilometres of sea water are lifted in this manner into the atmosphere and again returned as rain. For this, nearly a fourth of the sun's energy that falls over the earth is utilized. The drops of water that fall on earth act like little vehicles carrying minerals from land into the sea, leaving the oceans the greatest depository of salts and minerals. Scientists have detected the presence of more than fifty elements in the sea water. For example, each cubic metre of sea water contains 0·008 milligram of gold. What makes it extremely difficult to collect these useful and costly metals and salts is the huge amounts of water involved-nearly ninety-six per cent of sea water is simply fresh water with only about four per cent in solids. Some of the minerals are in such a dilute form that we have yet to discover sufficiently sensitive instruments which can detect their presence. The water can, however, be separated from the salts either by freezing (when sea water is frozen, fresh water can be removed in the form of ice crystals) or by simple evaporation (exposing sea water to sun and wind in shallow salt pans).

Different methods and processes are employed in various countries for desalting. At San Diego, California, a process called 'Flash evaporation method' is used which costs Rs. 5·00 for 4,546 litres, and electrodialysis is in operation at Israel. Nuclear-powered desalting plants are being planned in California which can produce many billion litres a day at an estimated cost of about fifteen paise per 4,546 litres. Such a plant would also produce electricity at a cheap rate.

A third of the twenty-two million tonnes of common salt consumed yearly in the world is extracted from sea water, the rest being mined. The annual average consumption per head is about eight kilograms. From 1,000 cubic metres of sea water nearly 1·3 tonnes of salt can be separated. That the sea is an inexhaustible source of this most essential substance can be seen from the fact that its waters contain 38,000 million, million tonnes of this salt, a quantity that is estimated to last for nearly 17,000 million years.

Many other useful salts can also be commercially extracted from sea water. Sodium sulphate used in the manufacture of paper-pulp and glass, in medicines, in dyeing and in the preparation of cattle powders and caustic soda is one such salt. Other such salts present in sea water are magnesium chloride, magnesium sulphate, calcium sulphate and potassium sulphate. The light and strong magnesium highly useful in the aircraft industry for the manufacture of superlight alloys can be commercially extracted from sea water. By using magnesium the weight of alloys can be reduced by twenty to thirty per cent; three lakh tonnes are annually extracted at present from the sea. Potassium salts used in farming, photography, pharmaceutics, and in the manufacture of glass, soap, gun powder, etc. are present in sea water in sufficient quantities for commercial exploitation. In India 'bitterns', the solution left after the separation of common salt, rich in marine salts, is not used properly. Scientists feel that if efficiently processed it will be possible to recover in India at least 3 8 lakh tonnes of magnesium sulphate, 65,000 tonnes of potassium sulphate and 7,000 tonnes of bromine from salt bittern, annually.

Processes for the recovery of salts and metals must be so designed that during the process good fresh water can also be obtained as a side product and this, if planned properly, may prove to be economical. The process of desalting sea water is at present expensive, costing about Rs. 5·40 for 4,546 litres. Low cost caustic soda, bromine, flourine, chlorine, magnesium compounds, hydrochloric acid, soda ash and potassium compounds can also be produced from the thick brine after the fresh water is separated for human use.

Besides the much-needed food, water, chemicals and minerals, the sea can also provide us with miracle drugs. The varied forms of animals, plants and microbes that live in the sea might in the near future prove to be a limitless source of valuable pharmaceuticals. Many kinds of anti-biotics and other useful drugs can be obtained from the sea. The poison present in marine fish and other animals of the sea contains effective curative substances. One called holothurin, which exists in sea cucumbers, has been found to possess growth inhibiting properties and may prove effective for the treatment of cancer. Similarly, the poison of the toad fish has been found useful in combating diabetes.

Further, the sea bottom is a huge store of valuable ores. Large quantities of manganese, iron, copper, cobalt and nickel, phosphorus, etc. occur on the ocean floor in the form of lumps called nodules. New techniques and devices are being developed to bring these to the surface. Recently engineers have used methods to suck them off the sea floor.

The sea is a huge reservoir and transformer of the heat of the sun. It is also a transformer of the energy of the wind as well as the cosmic energy of the moon's attraction. Thus the sea represents a gigantic source of energy. It is possible to produce electric power from the sea. In one method the generation of power is from the thermal energy of the sea on the principle that the change of heat into energy requires a hot source and a cold source. In 1954 the consumption of electricity of the world was 1,345,000 million kilowatt hours and the demand for electric power is increasing at an annual rate of seven to ten per cent. The hydroelectric power capacity of all the rivers on our planet equals 3,750 million kilowatts. The energy of the tides in the oceans is estimated at 1,000 million kilowatts. If even a part of this energy is harnessed, it will be a substantial contribution to the world's power resources.

Every day the need for fresh water is increasing. The expected increase in population demands greater food production on land and this depends on the skilful management of water resources. Ritchie Calder, an authority on the use of water, has estimated the amount of water needed for the major agricultural crops. To grow a tonne of sugarcane by irrigation, about 1,000 tonnes of water must be consumed.

A tonne of rice requires 4,000 tonnes of water and a tonne of wheat about 1,500 tonnes.

At present only about four per cent of the total river flow is used to irrigate 125 million hectares of land which represent one per cent of the land area of the Earth. To feed a population which is estimated to reach 4,000 million by 1980 and more than 6,000 million by 2,000 A.D. extended irrigation farming and more intensive cultivation are essential. For this, availability of water is a vital factor.

It appears obvious that the different aspects of the oceans of the world need to be understood in much greater detail than at present for the effective utilization of their vast potential resources. Until now man has been able to exploit only a very tiny fraction of what the sea can offer him. This is partly due either to our ignorance or incomplete knowledge about this portion of the Earth. While our knowledge of the Mediterranean, the Atlantic and the Pacific is fairly satisfactory, we know very little about the Indian Ocean which borders the most thickly populated regions of the world.

In 1962 a project known as International Indian Ocean Expedition was undertaken by a Special Committee on Oceanic Research of the International Council for Scientific Unions, a non-governmental organization, with the object of carrying out large-scale scientific studies of the Indian Ocean. UNESCO is co-sponsoring the project with organizational and technical assistance. An unparalleled international co-operative endeavour, this expedition represents the most intensive oceanographic research project ever undertaken. Forty-five research ships and several scientists from twenty-five nations are making a combined attempt to collect scientific data methodically through well planned programmes. The

United States is a major participant in this concerted effort, and has provided nearly a dozen research vessels and several airplanes for making meteorological observations. It is hoped that the valuable data thus collected may help us to learn as much as possible about the Indian Ocean and provide a basis for the effective exploitation of its resources. This will certainly contribute substantially to the food and mineral output in bordering areas, thereby releasing millions from hunger, poverty and misery.